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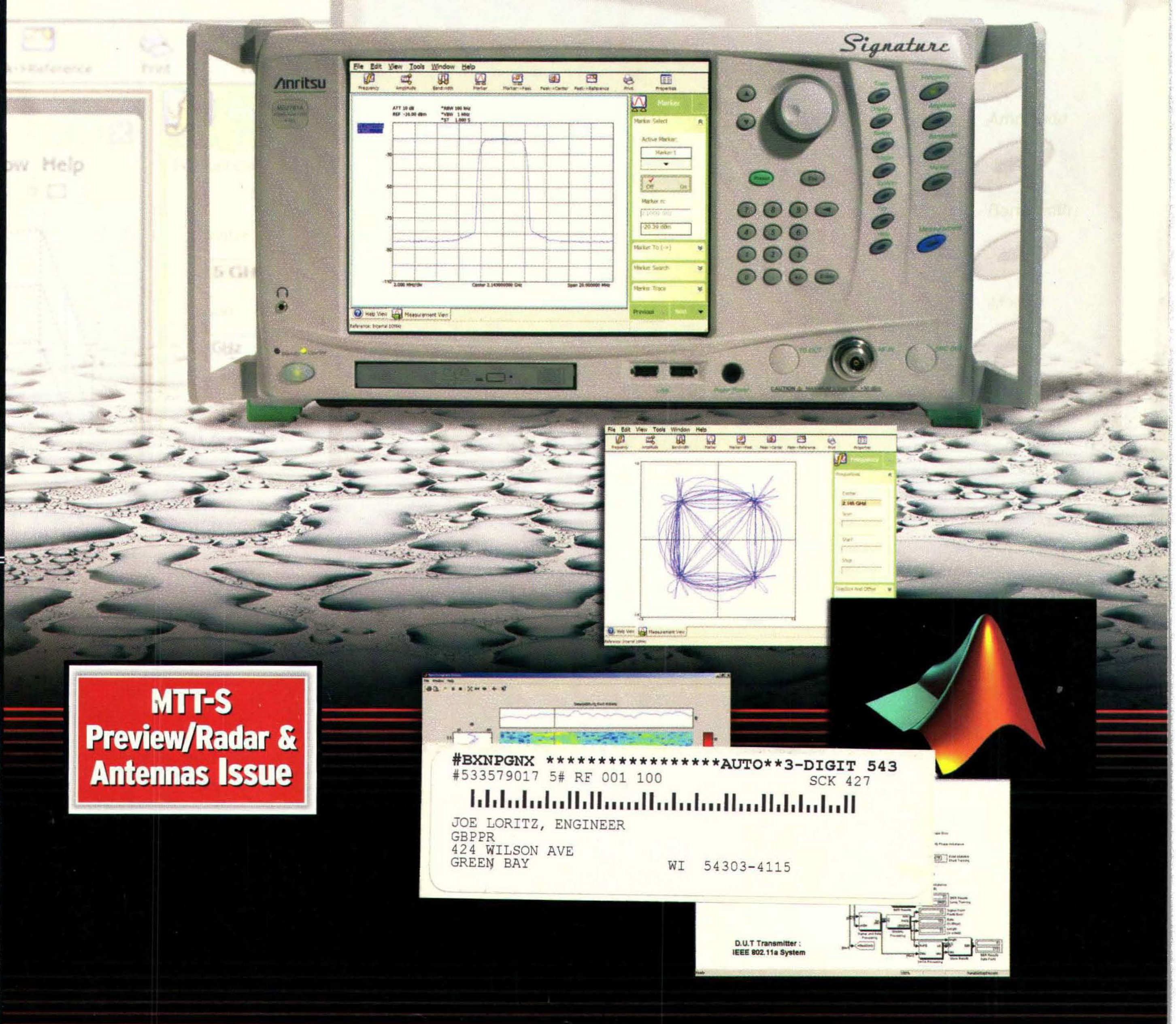
News
Microwave show brings technology to Texas

Design Feature
Selecting antennas for minimum interference

Product Technology
Filter search program performs magic

Smart Signal Analyzer Decodes 100 Hz To 8 GHz



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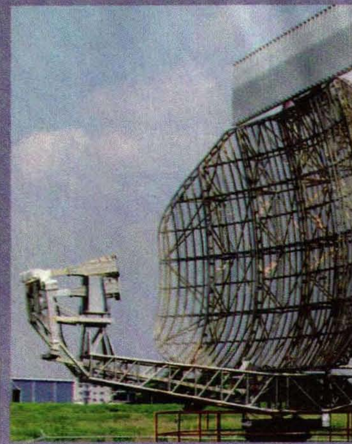

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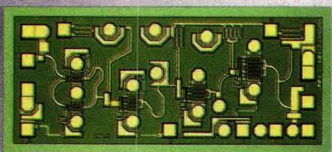
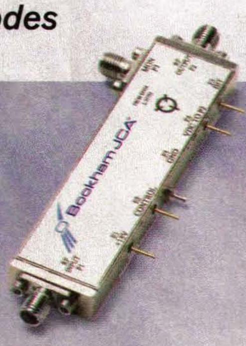
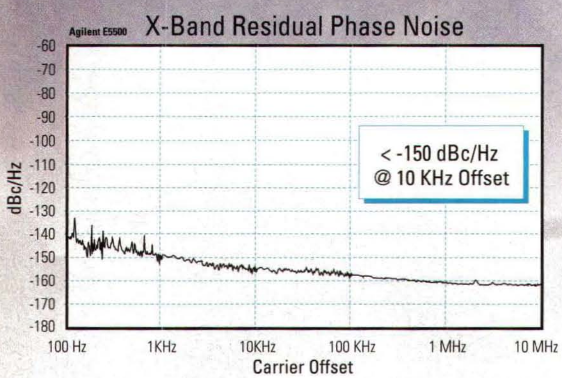
P35-5114-000-200	20–32	21	2.2	7	2	48
P35-5122-000-200	8.5–10.5	18	–	25	5	270
P35-5123-000-200	20–26	12	–	23	4.5	140
P35-5127-000-200	25–30	10	–	22	4	140
P35-5140-000-200	20–40	20	–	21	4.5	192





Broadband Power Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Orde ICP typ
JCA218-3000	2.0–18.0	23	4.0	2.5	23	28
JCA218-3001	2.0–18.0	30	4.0	2.5	25	30
JCA218-3002	2.0–18.0	34	4.0	2.5	27	32
JCA218-4000	2.0–18.0	33	4.0	2.5	23	28
JCA218-4001	2.0–18.0	40	4.0	2.5	25	30
JCA218-4002	2.0–18.0	44	4.0	2.5	27	32
JCA218-5000	2.0–18.0	43	4.0	2.5	23	28
JCA218-5001	2.0–18.0	50	4.0	2.5	25	30
JCA218-5002	2.0–18.0	54	4.0	2.5	27	32
JCA618-4001	6.0–18.0	40	5.0	2.0	33	40



Low Noise Amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Orde ICP typ
JCA12-1000	1.2–1.6	25	0.8	0.5	10	20
JCA12-3001	1.0–2.0	40	0.8	1.0	10	20
JCA14-400	1.0–4.0	40	0.9	1.5	15	25
JCA34-301	3.7–4.2	30	1.0	0.5	10	20
JCA48-4001	4.0–8.0	42	1.0	1.5	15	25
JCA910-3000	9.0–9.5	25	1.3	0.5	13	23
JCA812-5001	8.0–12.0	45	1.5	1.5	10	20
JCA1218-5001	12.0–18.0	48	1.7	1.5	10	20
JCA1819-3001	18.1–18.6	25	2.0	0.5	10	20
JCA2021-3001	20.2–21.2	25	2.5	0.5	10	20

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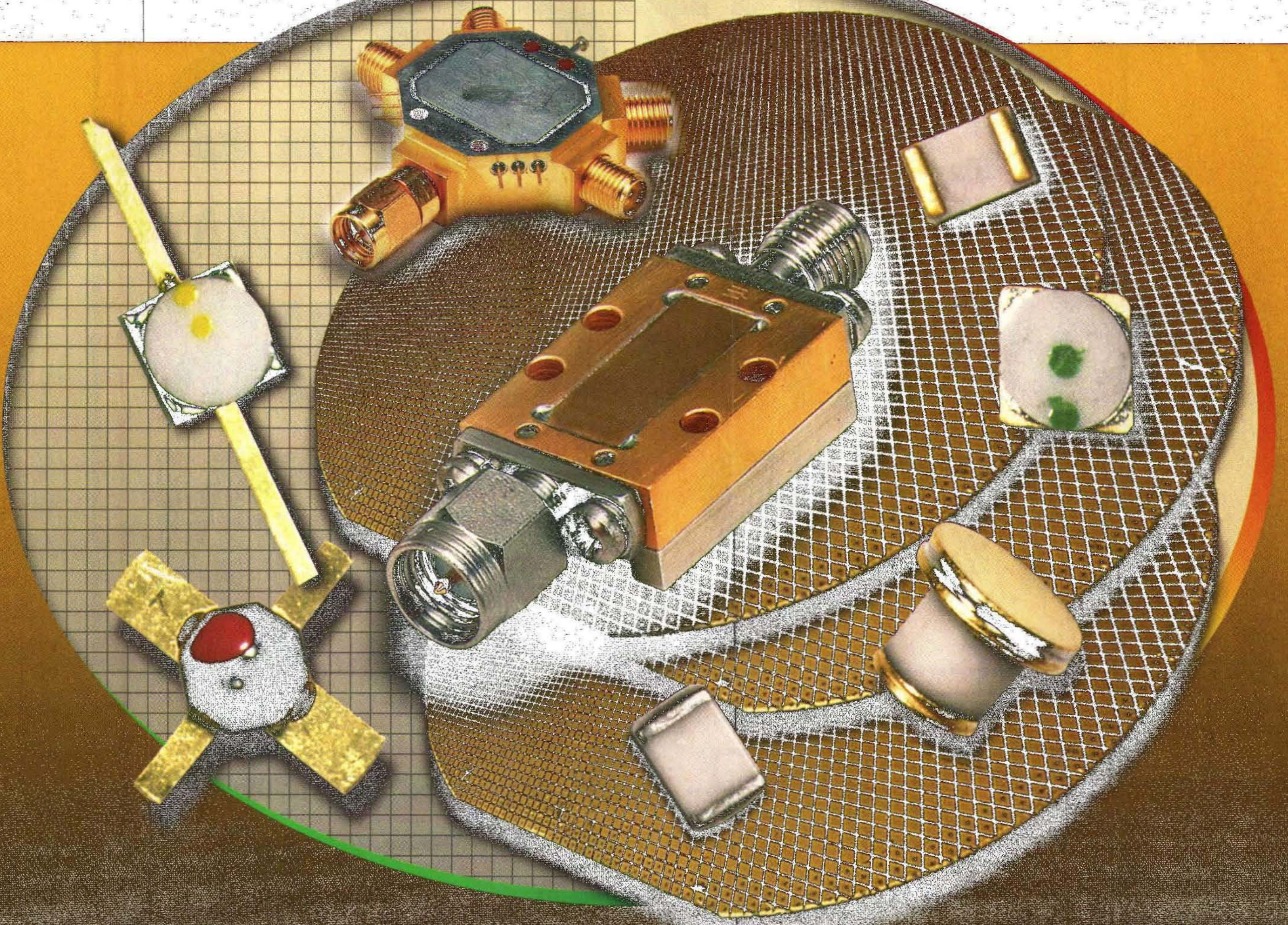

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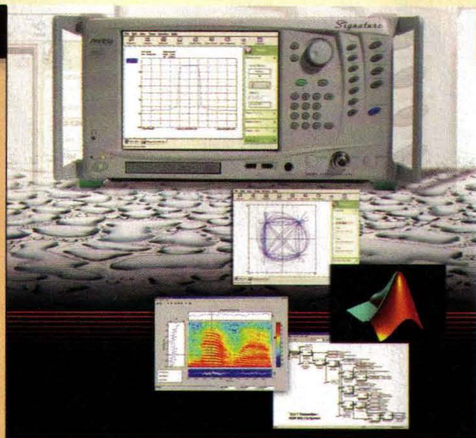

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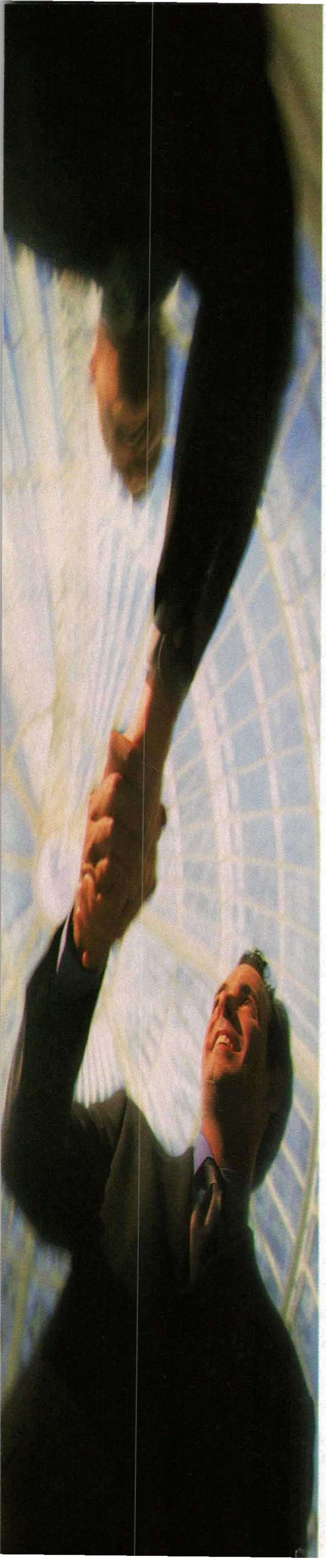


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Author Correction

▶▶IN THE AUTHOR CONTACT section of the Cover Story of your March issue ("Module Merges 11.5 Gb/s NRZ/RZ Converter, Driver," March 2004, p. 108), you misspelled the name of the article's author, Paolo Tabacco. In the magazine, it is spelled as "Paola." It is a minor typo, but Mr. Tabacco is the author as well as our vice president of engineering, so we thought that a correction was in order.

Mahvish Bari
Marketing Communications Analyst
iTerra Communications

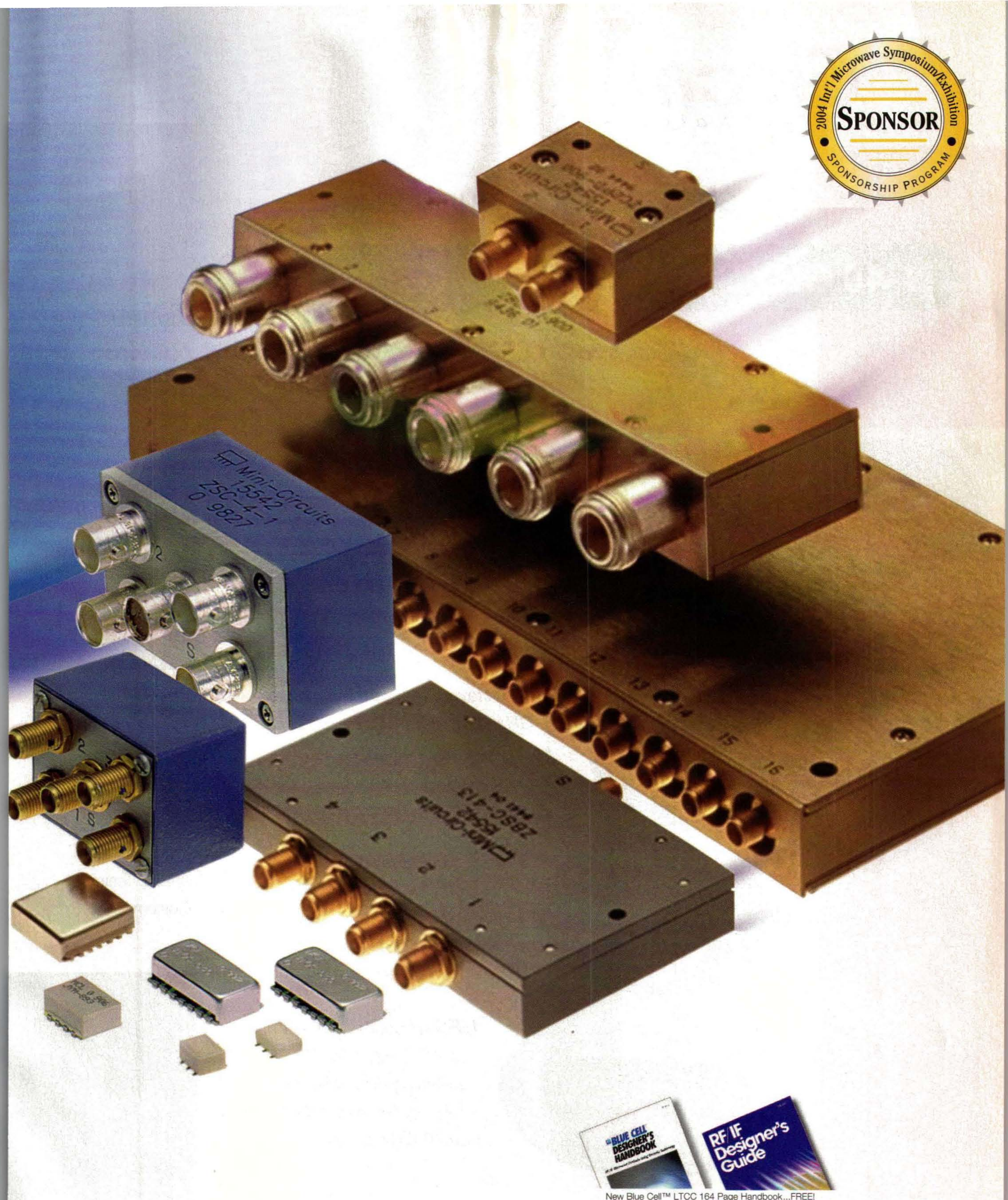
Editor's Note: We apologize to Mr. Tabacco, iTerra Communications, and our readers for the error. Please note that the spelling of Mr. Tabacco's name has been corrected in the Internet version of the article. Readers can find that article, as well as our other feature articles, at www.planetee.com.

San Diego WSD Conference

▶▶THIS WAS THE FIRST YEAR that we attended the Wireless Systems Design Conference & Exhibition (March 8-10, 2004, San Diego Convention Center, San Diego, CA) under the wing of our new parent company, Fairchild Semiconductor Co. We, formerly the commercial division of Raytheon Co., had attended this show for many years prior but this year both the location and the corporate name were new to us. In anticipation of a smaller show (which we assumed by talking to our competitors and customers, and checking the website exhibitors list), we scaled back on the 'extras' and cut three people off of our booth duty/attendance list. This was also a cost-cutting tact for us, the RF Power Group of Fairchild, especially since most of the personnel and the physical booth were being shipped from the Northeast.

In hindsight, it was the right move. Although most of the 'show regulars' were in attendance, a number of our prominent competitors were not. The first and second days of the show yielded about the same amount of traffic, and the third day was noticeably barren. Some of the show's slowdown can be attributed to a couple of factors: there have been various industry mergers and acquisitions, most companies are still in economic-recovery mode, and, possibly, the new location and weekday shift had something to do with the volume of traffic. I am hopeful, however, that future shows directly target and attract key customers' designers and decision makers. With the industry beginning to show signs of improvement, this should come to pass.

Catherine Austin
Business Development Manager
Fairchild Semiconductor, RF Power Group
Tyngsboro, MA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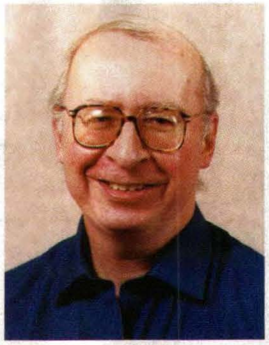
That Other June Trade Show



HIGH-FREQUENCY ENGINEERS ARE making their travel plans this June for Fort Worth, TX, to attend the industry's largest trade event, the IEEE Microwave Theory & Techniques Symposium (MTT-S). But there is another trade show that month that may have increasing interest for RF and microwave engineers, especially as the high-frequency industry matures and branches out into industries beyond the traditional commercial and military areas. That trade show is the Medical Design and Manufacturing East (MDM East) Conference and Exhibition.

The growth of MDM East (and MDM West) is in no small part tied to the aging of the country's large "Baby Boom" generation and their vested interest in health care.

Admittedly, the MDM East (www.mdmeast.com), scheduled for June 14-17, 2004 in the Jacob Javits Convention Center (New York, NY), is no MTT-S in terms of conference content. What the MDM East does offer is an exhibition floor that has grown steadily during the last few years with devices based on RF/microwave technology and with exhibitor booths from companies offering contract design and manufacturing services.

Apparently, developers of medical devices and equipment are not RF experts, although they recognize the value of embedded RF capability within their products. Several exhibitors at last year's MDM East, for example, showed telemetry systems based on the Bluetooth 2.4-GHz short-range communications protocol.

The growth of the MDM East (and its sister event, MDM West) is in no small part tied to the aging of this country's large "Baby Boom" generation and their vested interest in health care. Last month, the event's organizer, Canon Communications (www.canontradeshows.com) announced that sales for exhibit space were already 15 percent ahead of last year's final exhibitor count, and that a sellout of the show's exhibit floor space was imminent. The organizers expect 1750 exhibiting companies and more than 32,000 attendees.

Of course, the majority of the exhibitors offer labeling equipment, molding services, and pharmaceutical packaging. But within the mix is a growing group of electronic contract manufacturing and design companies, as well as electronics suppliers who recognize the opportunity in the medical industry. For example, last year's event featured a number of electronics firms, including materials supplier ARC Technologies (Amesbury, MA), electronic components distributor Mouser Electronics (Mansfield, TX), contract design specialist Pinnacle Electronics, and PCB prototyper Rapid Circuits (Levittown, PA).

The growth of the high-frequency industry depends on diversification into automotive, industrial, and medical applications. While our editors will be covering the MTT-S, they will also attend MDM East, and offer a wrap up in the August issue of *Microwaves & RF*.

Jack Browne

Publisher/Editor

Microwaves & RF

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AG202	15 dB	+20 dBm	+7 dBm
AG203	20 dB	+20 dBm	+7 dBm
AG302	15 dB	+27 dBm	+13 dBm
AG303	20.5 dB	+27 dBm	+13 dBm
AG402	15 dB	+33 dBm	+17 dBm
AG403	20.5 dB	+32 dBm	+17 dBm
AG503	19 dB	+29 dBm	+15 dBm
AG602	14 dB	+33.5 dBm	+18.5 dBm
AG603	17.5 dB	+33.5 dBm	+18.5 dBm
AG604	21 dB	+33 dBm	+18 dBm

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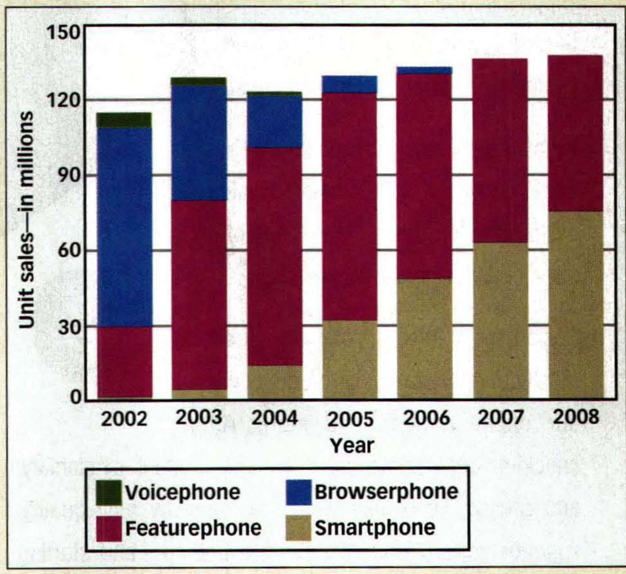
Western Europe's Mobile-Handset Industry Arrives At A Critical Technology Juncture

BOSTON, MA—According to a report from The Yankee Group, the mobile industry is now at a critical juncture as the migration from voice to data 2.5G and 3G environments finally takes place. Mobile handsets will play a critical role as enablers and as the interface to new and unfamiliar mobile data applications. The challenge for vendors and operators will be to maintain handset sales growth with features that consumers will actually use and value, while maintaining healthy profit margins.



Handset sales surged in 2003 propelled by a wave of new devices with color screens, MMS, and integrated cameras. As industry and technology changes push component costs lower, complex devices will permeate down into all user, handset, and price categories. The Yankee Group's report examines the evolving market for mobile devices in Western Europe, focusing on embedded handset features and the dynamics behind vendor, carrier, and consumer selection. Key conclusions of the report include: smartphones will account for the majority of sales in Western Europe by 2008 **(see figure)**, driven mainly by lower costs and supply-side migration to WCDMA; all new phones sold in 2007 will have Java and color displays, while Bluetooth and integrated cameras will not be ubiquitous; and the European mobile-terminal industry will fragment further, with many more vendors launching cheaper, yet more capable, devices.

Smiths Group Acquires TRAK Communications For $111.5 M

LONDON, ENGLAND—Smiths Group announced the acquisition of TRAK Communications, Inc., a firm involved in the design and manufacture of microwave subsystems, antennas, and related components, for $111.5 million from Veritas of New York. TRAK will form part of Smiths Interconnect, a supplier of application-specific electronics for military and commercial markets. This acquisition is the fifth that Smiths has announced since presenting its interim results on March 10, bringing total expenditure to $330.5 million.

On the subject of the acquisition, Smiths Group chief executive Keith Butler-Wheelhouse says, "Smiths continues to pursue its strategy of profitable growth through investing in new technology and the acquisition of businesses which complement or expand our offering to the customer. This is our fifth purchase announcement in five weeks and underlines our intent to acquire high-growth companies."

TRAK, with 425 employees and 2003 turnover of $71 million, operates from facilities in Tampa, FL, Thousand Oaks, CA, and Dundee, Scotland. Smiths Group is satisfying the acquisition consideration in cash. It will close at the end of this month, subject to regulatory approvals.

Einar Lindh, group managing director of Specialty Engineering, adds, "TRAK brings a portfolio of world-class microwave subsystems, which is complementary to Interconnect's products. It will extend our capability in existing markets, and by packaging together Interconnect and TRAK products, we will enhance our position with customers."

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DAC4103	0.01-4.0	-10 to 25	0.60	120	1.5	5	2.0
DAQ6104	0.1-6.0	-25 to 12	0.75	190	0.3	5	2.0
DAS8121	0.5-8.0	-30 to 5	0.50	140	0.02	5	9.0
DAQ10501	0.05-10.0	-30 to 5	0.75	120	1.5	5	2.0

THRESHOLD DETECTORS

Model	Freq. Range (GHz)	Input Power Range (dBm) Typ.	Power Flatness (±dB) Typ.	Hysteresis (dB) Typ.	Pulse Response (μsec) Typ.	DC Volts (±V)	Sup. Cur. (±mA)
DTC4001	0.01-4.0	-30 to -5	0.50	0.2	50	5	2.5
DTQ6001	0.1-6.0	-30 to -5	0.50	0.2	50	5	2.5
DTC6002	0.01-6.0	-30 to -5	0.50	0.2	50	5	2.5
DTS6014	0.1-6.0	-12 to 12	0.50	0.3	0.8	5	2.0

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Enterprise To Drive Dual-Mode Cellular/Voice Over Wi-Fi Handsets

OYSTER BAY, NY—According to "Voice over Wi-Fi (Vo Wi-Fi): Client Devices, Forecasts, Network and Design Issues," a report from ABI Research, shipments of dual-mode cellular/voice-over-Wi-Fi-enabled handsets will top 50 million by 2009. Though products are not expected to be available until later this year, ABI Research predicts that dual-mode cellular/voice-over-Wi-Fi handsets will represent about 7 percent of all handsets shipped by 2009. Driving the near-term interest in these devices are the enterprise user and the need for data-intensive applications.

Ease of use, the convenience of mobility, and access to information stored on cell phones has made it more practical for office users to continue to use their cell phones versus switching to the enterprise telephone system when at the office. But with near 30 percent of cell phones being purchased by commercial concerns, enterprises will likely be prime target buyers for voice over Wi-Fi cell phones.

"Many enterprises now have established Wi-Fi networks and integrating voice-over-WiFi functionality is a natural progression," says Phil Solis, senior Wi-Fi analyst at ABI Research. "As Wi-Fi networks proliferate, it only makes sense to give users the ability to switch from the cellular carrier's network to the enterprise Wi-Fi network."

Manufacturers are also working on the issues of integrating the Wi-Fi network with the company PBX, a requirement for voice-over-Wi-Fi-enabled handsets to remain useful as a voice device outside the enterprise Wi-Fi data network.

Currently, the voice-over-Wi-Fi market is limited to niche verticals such as healthcare, warehouse, manufacturing, and education. But with larger-scale availability by way of integration into existing mobile devices, this market will gradually become mainstream.

"VoIP will have a fundamental impact on all aspects of US telecoms because it causes fragmentation of supply and services offered."

VoIP Is Seen As A Turning Point For Telecom Firms In The US

WASHINGTON, DC—The rapid growth of voice over Internet protocol (VoIP) services in the US represents a turning point in the development of the US telecoms market, according to a report, *VoIP in the US Market: services, business models and regulation*, from Analysys Research, a global advisor on telecoms, IT, and media.

"VoIP will have a fundamental impact on all aspects of US telecoms because it causes fragmentation of supply and services offered," says Michael Kende, co-author of the report and a principal consultant within Analysys' Washington, DC office. "The US voice market will finally lose its monolithic character but VoIP is unlikely to replace traditional PSTN voice during this decade."

According to Analysys forecasts, by 2008, VoIP penetration is expected to reach 17 percent of broadband-enabled households (growing from under 1 million at the end of this year to 11.7 million in 2008). Together, consumers and small businesses are expected to provide almost 13 million VoIP subscriptions and $5.7 billion in annual service revenue in 2008. Although this is a significant amount, it represents 2.5 percent of the 2003 total US telecoms revenue of $224 billion.

For medium and large businesses, VoIP growth is also very strong. Analysys expects the estimated installed base of IP station lines to increase from just over 3 million in 2004 to more than 18 million by the end of 2008. This represents a compound annual growth rate (CAGR) of over 50 percent.

The report states that during 2003, VoIP broke simultaneously into the market consciousness of the US consumer, major industry telecoms players, and regulators with its promise of huge cost savings. Major service providers, such as AT&T, MCI, Time Warner Cable, Verizon, and others, made startling announcements to roll out and expand VoIP services and network deployment.

"VoIP has now moved from a behind-the-scenes network-migration strategy to a distinct billable service, separable from the underlying network, controllable by the end user, and with its own pricing schemes, features, and terminal equipment," comments Kende. "In doing so it has the potential to shift market power to the end user and new service providers, to disrupt the balance of universal service subsidies, and to redefine the geographical and technological basis of the US telecoms industry and its regulatory structure."

The report acknowledges that VoIP providers face a raft of potential regulatory impositions and decisions that will have a major impact on their business models.

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S3W2	S3W5	N3W5	3	±0.40
S4W2	S4W5	N4W5	4	±0.40
S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
S20W2	S20W5	N20W5	20	±0.60
S30W2	S30W5	N30W5	30	±0.85
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The DSP Market Enjoyed A Healthy Second Half In 2003

TEMPE, AZ—A report from Forward Concepts (www.forwardconcepts.com) states that the DSP chip market had a very healthy second half in 2003, with wireless and consumer market segments providing most of the gain. The final 2003 DSP revenue number from WSTS (World Semiconductor Trade Statistics) group was $6.13 billion, representing a 26.3-percent growth over 2002. Consumer shipments (in dollars) grew 109 percent, followed by wireless at 32 percent. Automotive, which consists mostly of entertainment equipment (stereos, GPS, etc.) and a small amount of power-train equipment (power steering, etc.), grew 17 percent.

"In the telecom business, last year was scraping the bottom."

As was apparent to all in the telecommunications business, last year was scraping the bottom, with only a 4.7-percent growth eked out in wired communications. Multipurpose, which includes catalog and distribution sales, was essentially flat, with a mere 1.5-percent growth.

The DSP computer and peripherals market is very heavily based on the hard-disk-drive (HDD) controllers. Although shipments appeared to be down some 33 percent, that's not the whole story. Agere Systems, the number-one supplier of HDD controllers in the world has begun to classify DSP controllers with PRML read channels on the same die as "SoCs." And such integrated chips are an increasing percentage of Agere's HDD controller shipments and they are now reported as ASICs, not as DSP chips. Moreover, the number-two supplier of HDD controllers is STMicroelectronics, and they do not report their millions of such chips as DSPs, either.

Infineon, the third-largest supplier of DSP baseband chips for the cell-phone market (after TI and QUALCOMM), reports zero DSP shipments, because they consider *all* of their DSP implementations as ASICs.

These are indications that the DSP market is far bigger than is reported, but DSP is slowly losing its identity as a separate, off-the-shelf chip as more DSP implementations become parts of SoCs.

Kudos

DUNEDIN, FL—Ocean Optics, Inc. has earned the 2003 Photonics Circle of Excellence Award for its LIBS200+ Laser-induced Breakdown Spectrometer System (LIBS), the world's first LIBS system to provide full spectral analysis from 200 to 980 nm at 0.1 nm resolution (FWHM) in a single laser pulse.

The Photonics Circle of Excellence Award is bestowed annually on the 25 most technically innovative new products of the year, as judged by the members of the *Photonics Spectra* magazine editorial advisory board.

HUDSON, MA—Accumet Engineering Corp., a Massachusetts-based company specializing in ultra-precision service for lapped and polished dielectric substrates, announced that have earned company-wide ISO 9001:2000 certification through the certification body of TUV America, Inc.

CHICAGO, IL—Concourse Communications has reported that it continues to experience double-digit usage growth in its airport Wi-Fi networks. During the first quarter, monthly growth rates in user sessions were over 35 percent. The most rapid usage increase is in Detroit Metropolitan Wayne County Airport, which went into service in January.

RICHARDSON, TX—CSR plc, a provider of single-chip radio devices, has won the internationally renowned Queen's Award for Enterprise, its third business accolade so far this year. The Queen's Award for Enterprise, International Trade category, follows the success of CSR's recent IPO (initial public offering) on the London Stock Exchange, the industry's biggest UK technology flotation for three years.

The Award recognizes achievement in international trade, demonstrated by outstanding growth in overseas earnings and commercial success. Previous recipients of the Queen's Award include TTPCom and Nortel Networks. CSR's ongoing achievements were also reflected by its IPO on the London Stock Exchange, which netted 89 million UK pounds (approximately $158 million US), earning the title of the largest UK technology IPO of the last three years.

In February of this year, CSR was named the East of England Business of the Year, making it the only company to have won in four different categories of the regional business awards—including being awarded private company of the year 2002. March 2004 saw CSR pick up the Cambridge Evening News Business Excellence Award for business of the year 2003.

GREENSBORO, NC—RF Micro Devices, Inc. announced the patent award of US patent number 6,701,138 for its method of integrated power control, which is based on collector voltage control. MRF

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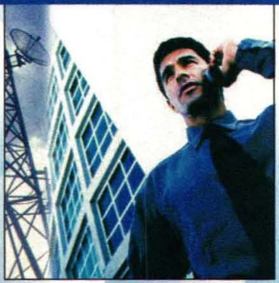

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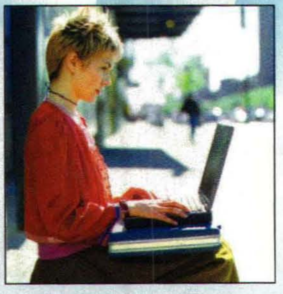

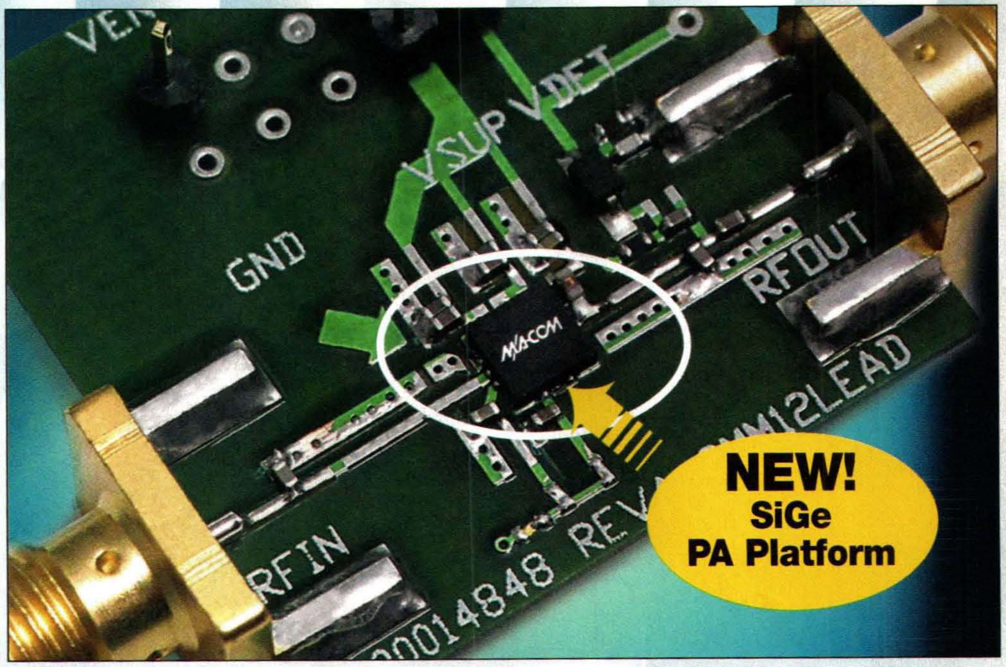

Power Amplifiers

Application	Freq. (GHz)	Gain (dB)	Pout (dBm)	Ids (mA)	Voltage (V)	P/N	Features
802.11b/g	2.4	31.5	18.5	150	3.3	MAAPSS0075	w/detector
PHS	1.9	32	23	240	3.5	MAAPSS0082	
DECT	1.9	30	26	400	2.4	MAAPSS0071	
DECT	1.9	30	26	400	2.4	MAAPSS0076	low power mode
WDCT	2.4	30	26	400	2.4	MAAPSS0066	
WDCT	2.4	30	26	400	2.4	MAAPSS0081	low power mode

Other M/A-COM products for WLAN and Cordless applications

Switches

Topology	Freq. (GHz)	IL@2.4 GHz (dB)	Isolation@ 2.4 GHz (dB)	P1dB (dBm)	P/N
SPDT	2.0-6.0	0.55	28	30	MASWSS0070
SPDT	2.0-6.0	0.70	28	36	MASWSS0093
SPDT	2.0-6.0	0.55	22	30	MASWSS0113
DPDT	2.0-6.0	0.80	43	29	MASWSS0094
DPDT	2.0-6.0	0.80	43	29	MASWSS0129
DPDT	DC-6.0	0.80	28	36	MASWSS0107
DPDT	DC-3.0	0.60	25	34	MASWSS0130

HMIC Mixers

Freq. (GHz)	Conversion Loss (dB)	LO-RF Isolation (dB)	Input IP3 (dBm)	RF VSWR (Ratio)	P/N
1.7-2.5	7.0	14	12	2.0:1	MA4EX240L-1225T
4.7-6.0	8.5	20	8.1	3.3:1	MA4EX580L-1225T
4.2-6.0	6.8	25	7.6	1.7:1	MA4EX600L-1225T

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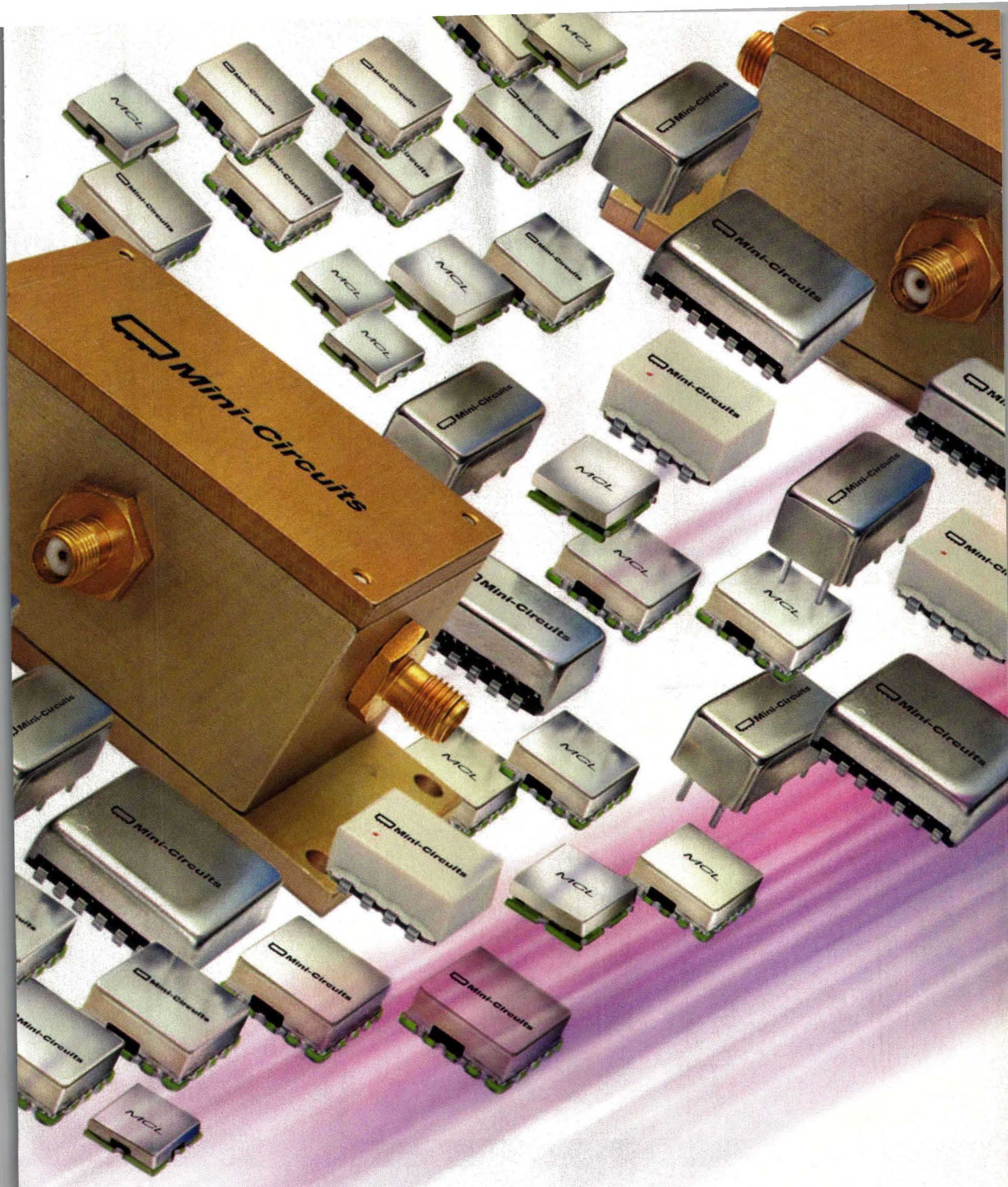
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Microwave Show Brings Technology To Texas

The industry's largest annual microwave conference and symposium gives attendees a chance to "cowboy up" amidst the history and western traditions of Fort Worth, TX.

JACK BROWNE
Publisher/Editor

Microwave week, as the calendar of events marking the IEEE's annual Microwave Theory & Techniques Symposium (MTT-S) conference and exhibition is known, offers a full schedule for the microwave engineer. Starting with full-day workshops on Sunday, June 6th, and carrying through the Automatic RF Techniques Group (ARFTG) conference and exhibition on Friday, June 11th, microwave week offers hundreds of technical presentations as well as hundreds of exhibitor booths for visitors to learn about the latest in microwave theory and product technology.

Scheduled for June 6-11, 2004 in the Fort Worth Convention Center (Fort Worth, TX), the MTT-S boasts a technical conference with 362 technical papers in 62 technical sessions, selected from 970 submissions for presentation. A total of 292 student papers were received for possible presentation, with 141 accepted (including for presentation in the interactive forums or "panel sessions" as they were once known), and 26 selected as finalists in a competition among student presenters. The MTT-S technical menu also boasts 35 workshops, nine panel sessions, and five tutorial sessions. In addition to the educational opportunities, the MTT-S and environs offer a full exhibition floor with much hardware, software, and test equipment on display, as well as professional opportunities for those seeking career changes **(see the sidebar).**

Tuesday's (June 8th) morning sessions include advances in Low-Noise Silicon Technology and Applications, with individual presentations on a 7.8-GHz BiCMOS low-noise amplifier (LNA) for ultra-wideband (UWB) applications, the performance of scaled MOSFETs, a wideband SiGe BiCMOS amplifier, and a 12-GHz heterodyne receiver for satellite-based digital-video-broadcasting (DVB) applications; Nonlinear Device Modeling, with presentations on a new physics-based dynamic electro-thermal large-signal model for RF LDMOS FETs, the effects of bias and load conditions on the dynamic self-heating of bipolar transistors, and a novel charge conservation model for predicting the nonlinear distortion of pHEMT devices; Theory and Design of Power Dividers, with presentations on a three-way low-loss phase combiner for power amplifier sharing in three-sector cellular networks and multi-stage microstrip power dividers with broadband properties; Spatial Power

Combining and Quasi-Optical Techniques, with presentations on a Ka-band grid amplifier array with over 10-W output power, power combining by means of harmonic injection loading, and an X-band spatial power combiner using a planar array of stacked patches for bandwidth enhancement; Mixed Signal Circuits from 10 to 144 Gb/s; and Microwave Superconducting Components and Circuits.

Also on Tuesday, afternoon sessions feature Advances in Low-Noise HEMT Technology, including a presentation from Northrop Grumman on InP HEMT low-noise amplifiers for phased-array applications; Frequency Conversion and Signal Control, including a presentation from Alcatel on a DC-to-100-GHz frequency doubler in InP DHBT technology; Novel Microwave and Millimeter-Wave Components; Millimeter-Wave MMIC Components and Subsystems, with a talk from Farran Technology on the design and analysis of a W-band multiplier chip set; Design and Characterization of Ferrite and Ferroelectric Devices, with a discussion on an analog tunale matching network using the unique BST material from Agile Materials and Technologies; and Microwave Generation by Optical

A total of 292 student papers were received for possible presentation, with 141 accepted and 26 selected as finalists.

Techniques, with individual presentations on arbitrary waveform generation by means of optical techniques, optical generation of microwave signals based on an unbalanced fiber loop mirror, and a 10-year review of the opto-electronic oscillator.

Tuesday afternoon's technical program continues with sessions on Metamaterials: Left-Handed Materials and Transmission Lines; Directional Coupler Techniques; Millimeter- and Submillimeter-Wave Components and Technology, including a joint presentation from M/A-COM and Mitre Corp. on periodic filters for performance enhancement of millimeter-wave microstrip antenna arrays and a student paper on terahertz-emitting devices based on boron-doped silicon; Microwave

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Dynamic Range		
NF (dB)	2.5	2.7
IP3 (dBm)	38	33

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Acoustic Devices; and Numerical Modeling for RF/Microwave Photonic Applications.

Wednesday morning's technical sessions offer presentations on MEMS Filters, including a tunable end-coupled filter, evanescent-mode filters, and a 60-GHz branchline coupler fabricated with integrated rectangular coaxial lines by the Air Force Research Lab; two sessions on Novel Packaging Techniques, including presentations on 120-GHz interconnects and a wafer-level package for bulk-acoustic-wave (BAW) devices; Filter Synthesis Techniques; Guided-Wave Structures and Effects; High-Power Amplifiers, including a 240-W Doherty GaAs FET amplifier from NEC Compound Semiconductor Devices; Advances in Wireless Communications Technologies, including an integrated multiband WLAN module fabricated on low-temperature cofired ceramic (LTCC); MEMS Switches; Filter Realizations; Remote Sensing and Measurement Systems; New Developments in Linear Amplifier Linearization; and Linear Device Modeling.

Reconfigurable Networks

Wednesday afternoon's sessions feature Reconfigurable Networks, with a presentation by Rockwell Scientific on a MEMS-based LTCC switch matrix as well as a band-switchable high-efficiency power amplifier using RF MEMS switches from NTT DoCoMo; Innovations in Broadband Communications and Radar, including a presentation on a single planar integrated self-heterodyne receiver with built-in steerable antenna array for 60-GHz video transmission systems from the Adaptive Communications Research Lab of ATR International; Numerical Modeling for RF/Microwave Photonic Applications, including presentations on numerical methods for microwave photonics and numerical modeling of segmented traveling-wave electroabsorption modulators; Nonlinear System and Device Modeling, including a talk from the University of Sydney on the contribution of self-heating effects to intermodulation distortion in FET devices; GaAs and GaN HEMTs and Monolithic ICs, including a presentation from Nitronex on GaN power transistors for wireless infrastructure applications; and Power Amplifier Enhancement Techniques.

Additional sessions on Wednesday afternoon are RF Varactors and Inductors, including a presentation

Making The Right Professional Match

JACK BROWNE
Publisher/Editor

Engineers sometimes welcome change, especially when they may feel a change of venue can make a difference in their careers. For those considering their professional options, the site of this year's MTT-S is also the location for a premier technology hiring event managed by Talware and sponsored by *Microwaves & RF* and *Wireless Systems Design* magazines. Scheduled for June 8th and 9th, from 7:00 a.m. through 7:00 p.m. in the Maddox-Muse Center of Bass Performance Hall, the Carnegie Hall of Fort Worth, TX, the event is designed to painlessly introduce qualified professional engineering candidates to leading companies involved in microwave/RF engineering, information technology, defense and aerospace electronics, and wireless technologies.

Organized by professional on-line search specialist Talware Hiring Events (www.Talware.com), and supported by the Defense Talent Network (www.DefenseTalent.com), a linked group of 14 on-line job boards including the *Microwaves & RF* site at www.mesmatch.com and the Association of Old Crows (AOC) site at www.jobs.crows.org, the hiring event encourages engineers to find their ideal positions in automotive, commercial, industrial, medical, and military high-frequency-electronics engineering areas. Job seekers are invited to preregister for the event and complete a detailed profile as well as post their résumés on Talware's proprietary profiling system. For those companies in need of talent, Talware's Virtual Scheduler helps to efficiently arrange one-on-one meetings with candidates.

For the companies in search of professional help, the Talware event works long after visitors have returned from the MTT-S, with a software-based system that provides unlimited access to resumes of profiles for 30 days after the event, with all of the sophisticated filtering, matching, and ranking features built into the system. And starting four weeks before the event, job candidates are reminded on a weekly basis of the hiring event and their potential opportunities to meet with "companies in need" of their help.

For more information on the hiring event, employers can visit the website at www.talware.com/Fortworth while job candidates can resister, create profiles, and post their résumés at www.talfinder.com/Forthworth, send an e-mail to hiringevent@talware.com, or call Emmanuel Sheafe at (757) 898-0171.

from the University of Michigan on analog MEMS varactors; VHF and UHF Technology Advances, with a presentation from the University of Zaragoza on the output-power capabilities of Class E power amplifiers and a talk from Oregon State University on high-efficiency Doherty amplifiers for GSM handsets; Microwave Acoustic Filters and Their Wireless Applications, including presentations on wideband BAW filters by TFR Technologies, coupled BAW resonator filters by Infineon Technologies, and film-bulk-acoustic-resonator (FBAR) filters and diplexers by Agilent Technologies; Advances in Nonlinear CAD Techniques, with a presentation from Villanova University on the distortion modeling of PIN diode switches and attenuators; Silicon Devices, ICs, and Emerging Technologies, with lecturers from the University of Stuttgart discussing a wideband, low-power CMOS transimpedance amplifier; and finally Ultra-High-Power Microwave Systems and Components, chaired by Barak Levush of the Naval Research Laboratory (NRL, Washington, DC), and including presentations on photonic bandgap (PBG) structures for high-power microwave applications, high-power microwave sources, active RF pulse compression for accelerator applications, and a half-gigawatt dual-moded X-band transmission and RF pulse compression system.

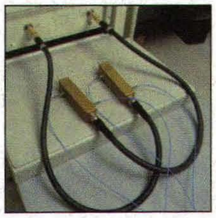
Panel Sessions

Panel sessions scheduled for June 9-11 include various views on MEMS technology in "Challenges and Solutions for Deploying New Microcomponent-Based Functions in Multiband Mobile Devices," organized by Didier Lecroix and Tom Breunig of Discera, Inc. (Campbell, CA); an examination of truly high-frequency devices in "Terahertz Technology Implications to Biological Sensing and Defense" organized by Dwight Woolard of the Army Research Lab (Adelphi, MD) and James Wiltse of Georgia Tech Research Institute (Atlanta, GA); and a review of printed-circuit-board (PCB) options for microwave circuits in "Should I Choose a Ceramic or Organic Board" organized by Rick Sturdivant of the fabless semiconductor company MMICMAN LLC (Orange, CA) and George Ponchak of NASA Glenn Research Center (Cleveland, OH).

Full-day tutorial sessions on the last day of Microwave Week include RF and Microwave Power Amplifier Design, with coverage of impedance matching, the use of power combiners and directional couplers, and designing for high efficiency. This

> ***The MTT-S technical menu boasts 35 workshops, nine panel sessions, and five tutorial sessions.***

session focuses on active device modeling, including nonlinear models for MOSFETs, MESFETs, HEMTs, and HBT devices, and highlights typical circuit implementations of power amplifiers for a variety of frequencies using different transistors. A second tutorial session is Fundamentals and Trends in Modeling and Simulation of High-Frequency Microwave Circuits, Interconnects, and Systems, which explains simulation of distributed interconnects and measured S-parameters, extraction of interconnect parameters, high-frequency interconnect models, and managing model complexity via model-reduction algorithms. This session deals with the difficulties of modeling high-speed interconnects and transmission lines in ways that traditional SPICE modeling techniques fall short. It will cover various interconnect models, including RC/RLC lumped models, distributed models, full-wave



models, and EMI-based models.

Workshops during the final day include Microwave and Millimeter-Wave organic System-on-a-Package Module Technologies, with coverage of RF system-in-package (SiP) devices, achieving cost and size requirements in laminate package solutions,

> ***Microwave Week** offers a special event for test and measurement professionals, the 63rd ARFTG Conference.*

quasi-hermetic packaging approaches, advanced design techniques for three-dimensional (3D) organic system-on-package (SOP) modules, current manufacturing techniques for 3D organic packages, demonstrations of organic SOP modules for communications applications, trends in high-speed integrated packaging, liquid crystal polymers for RF and millimeter-wave packaging, and 3D laser-based processing for high-Q embedded microwave components. The workshop will explore multilayer board techniques for applications through W-band (75 to 110 GHz).

Additional Workshops

Additional workshops include Microwave Filter Synthesis and Realization (with coverage of asymmetric coupled resonator filters, cascaded triplets and quartets, evanescent-mode filters, and planar bandpass filters), Model Order Reduction Methods and Applications [with coverage of passive model-order reduction of high-speed interconnects using integrated congruence transforms, parameterized and nonlinear model order reduction, model order reduction by Krylov space

methods, efficient model order reduction based on a two-step Lanczos approach, and a state-space/integral-equation (SS/IE) approach to the S-domain modeling of passive MMICs], Advances and New Directions in Device Modeling and Design Optimization for Microwave CAD (covering measurement-based frequency-domain nonlinear component modeling, integration of EM circuit and system design tools, modeling high-speed interconnects, accurate analysis of large spiral inductors, EM design through inverse spacing mapping techniques, coarse EM modeling of LTCC RF circuits and its applications to optimization design, and neural network based device modeling and design optimization), Tunability for Highly Selective Microwave Systems (with examinations of tunable dielectric and superconducting materials); Reliability Testing and Reliability Enhancement of RF MEMS Switches (with presentations on reliability testing of an RF MEMS Ohmic switch, reliability testing of RF capacitive switches, reliability testing of MEMS switches at Raytheon and Northrop Grumman, and RF power measurements of MEMS Ohmic switches); Signal Processing Receivers for Optical Fiber Communications (covering adaptive equalization for 10-Gb/s systems, 10-Gb/s adaptive electronic dispersion compensation, and adaptive sampling and filtering single-mode and multimode fiber links); Active Antennas (with presentations on packaging for active quasi-optics, active antennas based on SiGe MMICs, and RFID antenna integration), and Ultrafast Analog-to-Digital Converters (highlighting low-jitter clocks at 10 GHz, correlation ADCs for wideband digitization, superconducting ADCs, and photonic ADCs).

63rd ARFTG Conference

Microwave Week also offers a special event for test and measurement professionals, in the form of the 63rd ARFTG Conference. Held twice each year, the summer ARFTG meeting is traditionally held toward the end of MTT-S week. The theme for this 63rd ARFTG meeting is "On Wafer Characterization" with the obvious focus on measuring devices and ICs while still in wafer format by means of precision test probes and associated microwave test equipment, such as vector network analyzers, noise measurement receivers, and power meters. Technical presentations at the Fort Worth ARFTG, which is scheduled for the Radisson Hotel, Friday, June 11th, will include measurements for RF and satellite communications systems operating through 70 GHz, measurements on (balanced) differential components and devices, traceability to national standards laboratories, models for measurement verification, calibration and measurement procedures for vector network analyzers, and power and noise measurements. Note that ARFTG has its own website at www.arftg.org for more information about the group in general or the 63rd meeting in particular. MRF

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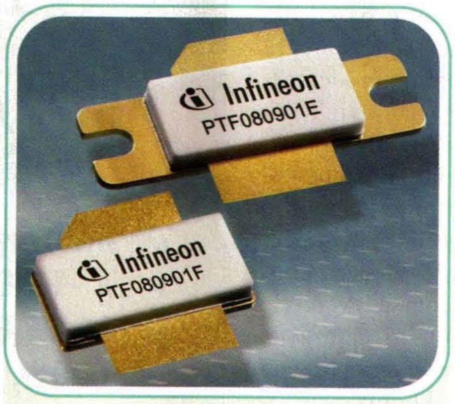
SUPPLIED IN A thermally enhanced package, the model PTF080901 GOLDMOS® field-effect transistor (FET) is well suited for EDGE and CDMA base-station applications. Typical CW output power is 120 W with 17-dB gain and 60-percent power-added efficiency. Under EDGE conditions, the single-ended device provides 45 W average power with 40-percent efficiency and 18-dB gain. The transistor boasts extremely low thermal resistance of 0.52°C/W. The rugged +28-VDC transistor is capable of handling mismatches equivalent to a 10.0:1 VSWR at 90-W CW output power.

Infineon Technologies NA, 18275 Serene Dr., Morgan Hill, CA 95037; (408) 776-0600, FAX: (408) 779-3108, Internet: www.infineon.com/rfpower.



INFINEON'S MODEL PTF080901 GOLDMOS FET

Gain Blocks Fit SOT89 Packages

MODELS HMC479ST89 AND HMC481ST89 are SOT89-packaged versions of two silicon-germanium (SiGe) gain blocks available previously in micro-X plastic packages. The new gain blocks are based on Darlington feedback device pairs internally matched to 50 Ω and requiring few external components. They are designed to operate on single positive voltage supplies of +5 to +12 VDC and can be cascaded for increased gain levels. The HMC479ST89 is designed for applications from DC to 5 GHz and provides typically 15 dB gain with +18 dBm output power and 4 dB noise figure. The HMC481ST89 is also designed for applications from DC to 5 GHz, but provides 20 dB gain with +19 dBm output power and 3.5-dB noise figure. The device is capable of 20 dB gain with +33 dBm output third-order intercept point at 1 GHz while drawing only 79 mA current. Samples and evaluation boards for both models are available from stock.

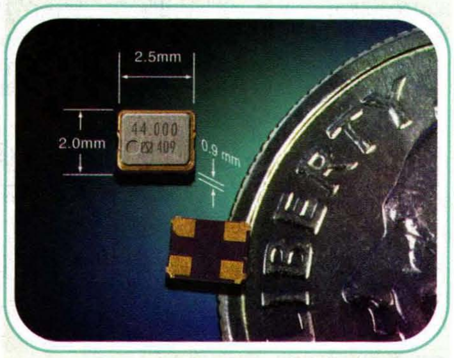
Hittite Microwave Corp., 12 Elizabeth Drive, Chelmsford, MA 01824; (978) 250-3343, FAX: (978) 250-3373, Internet: www.hittite.com.

HITTITE'S HMC479ST89 AND HMC481ST89 GAIN BLOCKS

SMD Packages Hold Crystal Oscillators

AMONG THE SMALLEST crystal clock oscillators in the world, the NZ2520 series is supplied in a surface-mount-device (SMD) package measuring just 2.5 × 2.0 mm with a thickness of just 0.9 mm and weight of just 0.02 g. Available at fixed frequencies from 1.5 to 67.5 MHz, the crystal oscillators provide CMOS drive levels and consume as little as 3.5 mA from a +3-VDC supply. Rated for an operating temperature range of –20 to +70°C, the oscillators exhibit frequency stability of ±30 PPM at temperatures from –10 to +60°C and ±100 PPM across the full operating-temperature range. Ideal as a clock source for portable devices such as Portable Digital Assistants (PDAs), the oscillators are lead free and meet the requirements of reflow profiling using lead-free solder. P&A: $1.40 (10,000 qty.).

NDK America, Inc., 701 Crystal Parkway, Belvidere, IL 61008; (800) NDK-XTAL (635-9825), (815) 544-7900, FAX: (815) 544-7901, e-mail: admin@ndkxtal.com, Internet: www.ndkxtal.com.



NDK AMERICA'S NZ2520 SERIES OF SMD PACKAGES

ASK Chip Receives 300 To 450 MHz

DESIGNED TO OPERATE in a wide variety of power-sensitive applications such as remote keyless-entry (RKE) automotive systems, car alarms, home-security systems, remote controls, and garage-door openers, the MAX7033 is a superheterodyne amplitude-shift-keying (ASK) receiver integrated circuit (IC) capable of –114 dBm sensitivity from 300 to 450 MHz. It can operate from either a +3- or +5-VDC supply and draws less than 1.6 μA in shutdown mode. The receiver consists of a low-noise amplifier (LNA), a fully differential image-rejection mixer, a 10.7-MHz intermediate-frequency (IF) limiting amplifier stage with received-signal-strength indicator (RSSI), and analog baseband recovery circuitry. P&A: $1.84 (10,000 qty.); stock.

Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: www.maxim-ic.com.

MAXIM'S MAX7033 ASK RECEIVER IC


Ceramic Resonator
Oscillators CHALLENGE
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PHASE NOISE
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
-150.0
-160.0
-170.0
100
1K
10 K
100K
1M
SAW @ 2488.32 MHz
CSO Series @ 2488.32 MHz
FEATURES:
• Low / Uniform Thermal Drift
• Small Size, Surface Mount
• Exceptional Phase Noise
+ 100°C
CSO SERIES
TEMPERATURE
SAW
- 40°C
New
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$AW
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RFMD Acquires Silicon Wave

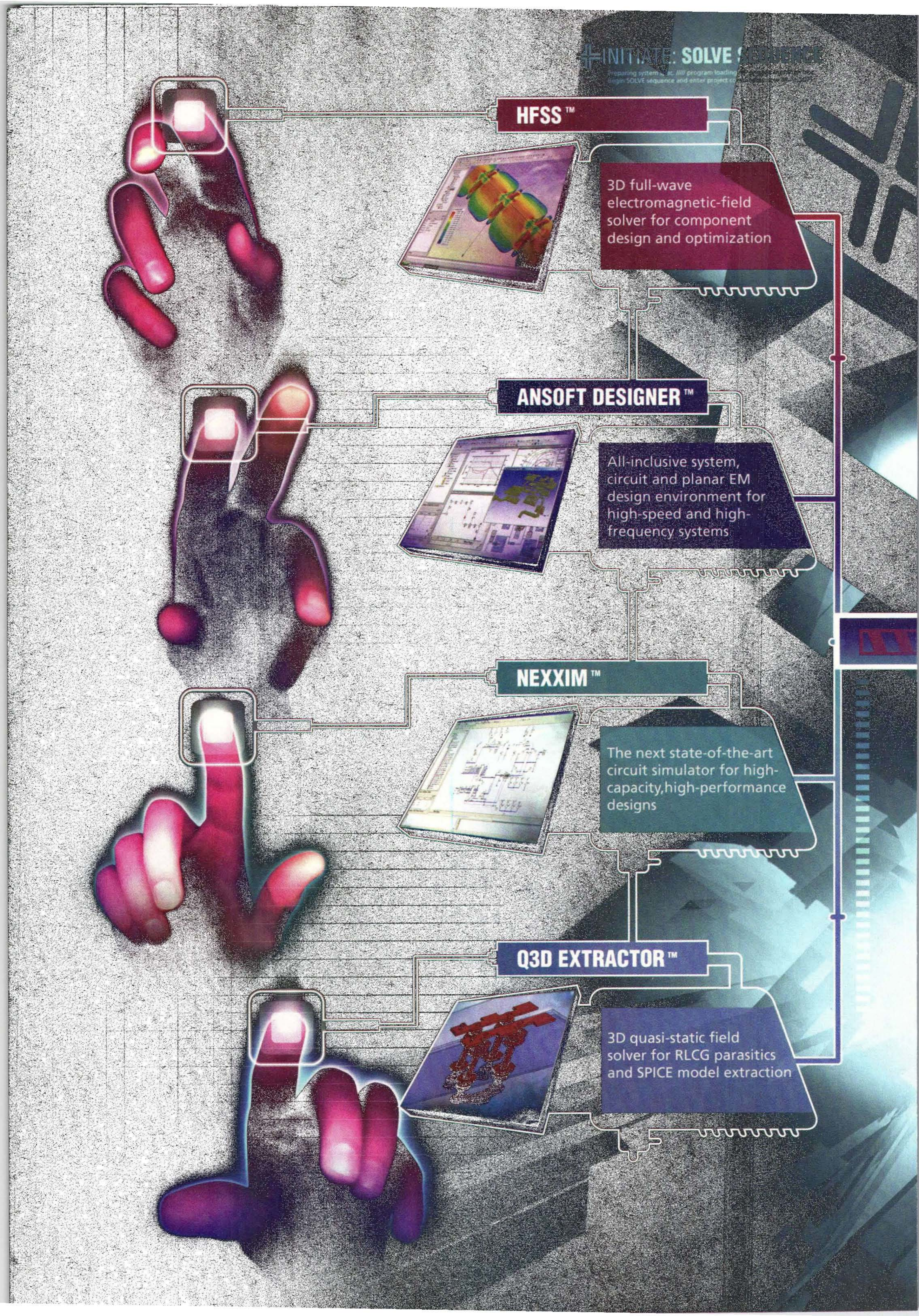
RF MICRO DEVICES, INC. (RFMD), a provider of proprietary RF integrated circuits (RF ICs) for wireless-communications applications, announced that it has signed a definitive agreement to acquire Silicon Wave, Inc., a privately held, San Diego-based company that is a supplier of ICs for wireless personal-area networks (WPANs).

Silicon Wave's Bluetooth® product portfolio includes highly integrated single-chip CMOS radio processors (including the radio modem and digital baseband functions), as well as stand-alone CMOS radio modem solutions. The CMOS Bluetooth radio processors have an architecture that does not require external flash memory nor external RF components, which represents a cost and size advantage compared to competitors' solutions. Silicon Wave's Bluetooth products are currently in production and in use supporting multiple applications, including cellular handsets, PC peripherals, and consumer electronics devices. Based on Bluetooth design activity, RFMD currently anticipates that quarterly Bluetooth revenue will increase sequentially throughout its current fiscal year ending March 31, 2005.

Stuart Carlaw, senior Bluetooth analyst for IMS Research, comments, "With the acquisition of Silicon Wave, RFMD puts itself in an extremely strong position to capture growth in the explosive Bluetooth market, which we anticipate will grow more than six-fold over the next three years. RFMD is a leader in the cellular PA market with a customer base that's ripe to leverage for Bluetooth sales. Silicon Wave is an emerging force in personal-area networks with highly integrated all-CMOS Bluetooth offerings that are gaining traction as standalone products."

In connection with the acquisition, RFMD will pay approximately \$10.8 million in cash in exchange for all outstanding shares of Silicon Wave capital stock not owned by RFMD. Additionally, if certain revenue performance goals for the years ending March 31, 2005 and 2006 are met, RFMD will pay additional amounts in cash to shareholders of Silicon Wave.

For more information about RFMD, visit their website at www.rfmd.com. MRF



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All-inclusive system, circuit and planar EM design environment for high-speed and high-frequency systems
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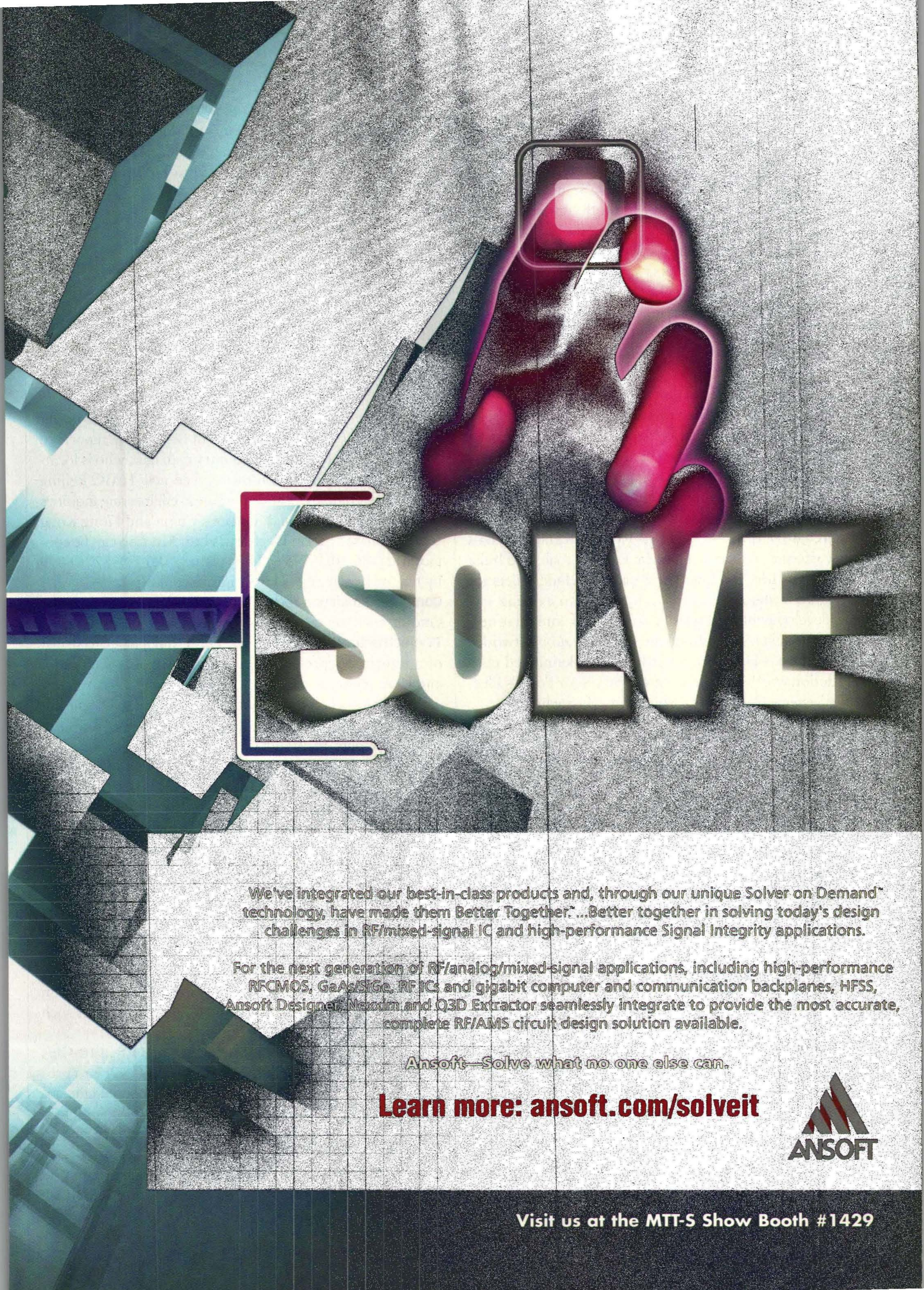
SOLVE
We've integrated our best-in-class products and, through our unique Solver on Demand™ technology, have made them Better Together.™...Better together in solving today's design challenges in RF/mixed-signal IC and high-performance Signal Integrity applications.
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CONTRACTS

Centro de Tecnologia de las Comunicaciones, S.A. (CETECOM)—Has been recently chosen by The State Radio Monitoring Center (SRMC) to supply Bluetooth conformance test solutions, BITE, in Beijing, People's Republic of China. This will allow SRMC to offer Bluetooth Qualification testing services to Chinese manufacturers.

As part of the contract, CETECOM will be delivering BITE RF and Protocols conformance testers and providing full training and technical support to help SRMC become an officially recognized BQTF (Bluetooth Qualification Test Facility), the first in Mainland China.

Alvarion Ltd.—Announced that it has received an additional order valued at $18 million for its advanced eMGW™ solutions from a Latin American telecom operator for further expansion of its 3.5-GHz wireless access network. The implementation of this phase of the expansion is expected in the second half of 2004 and the beginning of next year.

EMS Satellite Networks—Has received over $8 million in orders for purchase of EMS SatNet DVB-RCS hubs and terminals from customers in North America, Europe, Asia, and India over the last three months. These orders include orders for over 1000 terminals, as well as upgrades to existing systems, development platforms for integrators, and three new systems for military, VoIP, and distance-education networks.

Raytheon Co.—Has been awarded an undefinitized contract action worth $19.5 million by the US Air Force's Electronic Systems Center, Hanscom AFB, Massachusetts.

Raytheon will design, assemble, integrate, configure, test, and deliver Global Broadcast Service (GBS) receive suites that consist of either Air Force or 88XR Type-1 and Type-2, Internet Protocol (IP) receive broadcast managers and next-generation receive broadcast managers will be built to conduct environment qualification tests, prepare integrated logistics support products, and perform in the GBS developmental testing/operational testing. The work will be conducted in Reston, VA.

Racal Instruments—Announced an agreement to provide the US Navy with an additional six Jet Engine Test Instrument (JETI) systems, bringing the total complement of JETI systems to 14 installations in four different test-cell configurations: T-36A, T-6B, T-10B, and T-1A. Additionally, there will be one software-development version. The contract was awarded in Lakehurst, NJ, with requirements for four carrier-based systems, including an installation on the US Navy's newest aircraft carrier, USS Ronald Reagan, as well as two land-based systems.

Lucent Technologies—Has been awarded two contracts valued at $26 million by the US Department of Defense (DoD). One contract is worth $13.4 million for the second phase of the Coherent Communications Imaging and Targeting (CCIT) program. The other contract is valued at $12.5 million, and it is for the Integrated Router Interconnected Spectrally (IRIS) program. The goal of the CCIT program is to demonstrate new technologies for doing high-speed and long-range laser communication, while IRIS will focus on the next-generation of super-fast, ultra-high-capacity optical communications.

FRESH STARTS

Hittite Microwave Corp.—Has opened a fifth international office, Hittite Microwave CO. Ltd., located in Beijing, People's Republic of China. This office will serve the expanding customer base in Northern China.

Mr. Caper Cao (Cao Li) is Hittite's district sales manager for Northern China, and is based in Beijing. He reports to Mr. Hualiang Xiong, China country manager, who is located in the Hittite Shanghai office. The new HMC Beijing office will support sales and application engineering inquiries both directly and through Hittite's China and Hong Kong representative WaiTat Electronics Ltd. Mr. Cao can be contacted at (+86-10) -8775 6717 by phone, (+86-10) -8775 6899 by fax, or by e-mail at china@hittite.com.

Computer Simulation Technology (CST)—Announced that PCB Graphtec will serve as CST's representative in Singapore.

TT electronics IRC—Has added Thom Luke Sales to its list of authorized representatives for the Arizona, Colorado, and Utah regions.

With sales offices in Scottsdale, AZ, Denver, CO, and Salt Lake City, UT, Thom Luke Sales will represent IRC's full line of products, including thin-film precision resistors and networks, thick film-on-steel, power wirewound resistors, surface-mount cylindrical resistors, and advanced resistor technologies.

Iridium Satellite LLC—Announced the launch of a satellite fax service that will permit subscribers to send and receive faxes from any location in the world directly to and from any standard fax machine, as well as connect WiFi networks to Iridium.

The Iridium fax service supports inbound and outbound faxes through the uniHub™ interface, which has been developed by On-Go, Inc. of Bethesda, MD. UniHub is a plug-and-play solution that extends the functionality of Iridium satellite phones, to include fax and other data services such as WiFi integration.

Molex, Inc.—Has become a member of the Unified 10-Gb/s Physical-layer initiative (UXPi). The goal of UXPi is to promote a common physical-layer standard for serial chip-to-chip and backplane data transmission at 10 Gb/s. Molex joined UXPi to help develop and promote the standard and to bring expertise in the area of backplane connectors.

RF Micro Devices, Inc.—Announced that it has begun preproduction shipments of its POLARIS™ TOTAL RADIO™ transceiver solution. MRF

COSTA

Centellax Appoints Tally Costa To Sales VP Position

Centellax, Inc. has named RF industry veteran TALLY COSTA to the position of vice president of sales and business development. Prior to her recent appointment, Costa served as director for sales and marketing at Sirenza Microdevices.

AVCOM of Virginia, Inc.—PAT PIPER to director of worldwide sales; formerly satellite product manager at Richardson Electronics.

EMS Technologies, Inc.—JAMES CHU to director of advanced technology; formerly senior director of the Advanced Technology Center at Rockwell Collins.

Applied Wave Research, Inc. (AWR)—NORIYUKI SASAKI to the Asia Pacific sales team; formerly worked in a variety of management positions in applications engineering, sales, and solution services at Innotech Corp.

Schneider Electric North American Operating Division—HOWARD E. JAPLON to senior vice president, general counsel, and secretary; formerly deputy general counsel.

Rogers Corp.—ROBERT D. WACHOB to president and CEO; formerly president and COO.

2Wire—JOHN CAULFIELD to vice president of sales for North America; formerly head of sales at Vertical Networks. Also, TED FAGENSON to vice president of sales for Latin America and Asia Pacific; formerly international sales director.

Raytheon JPS Communications—JEFFERY D. CRITSER to vice president and general manager; formerly CEO of Trinity Convergence, Inc.

Anritsu Corp.—FRANK TIERNAN to president of Anritsu Co., the American subsidiary of Anritsu Corp., and vice president of the parent company, Anritsu Corp.; formerly division general manager for Anritsu's Microwave Measurement Division.

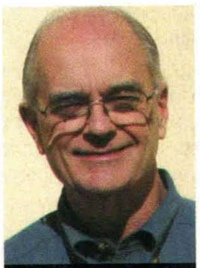
Labtech—MARK GULLOTTI to national sales manager for North America; formerly employed in sales positions with printed-circuit-board (PCB) and backplane manufacturers, assemblers, and value-added-system integrators.

Microfabrica, Inc.—DR. DAVID LAM to chairman of the board; continues as chairman of the David Lam Group and venture partner of Torrance, CA-based DynaFund Ventures.

Endicott Interconnect Technologies (EI)—JAY DESAI to vice president of sales; formerly vice president of sales and marketing for ISU Pentasys. Also, MICHAEL ARP to vice president and CFO; formerly vice president of finance for NFI Interactive.

Wireless Valley Communications, Inc.—JOHN JACOBS to director of product marketing; formerly vice president of business development at Accton Technology Corp. Also, DR. VEERA ANANTHA to director of engineering; formerly lead architect and project manager of wireless solutions at Intrinsity, Inc.

Trompeter Electronics—TOM BARBER to director of sales for the Semflex/Trompeter business group of STRATOS International; formerly director of operations.



BARBER

SINGMIN

SiGe Semiconductor, Inc.—ANDREW SINGMIN to quality manager; formerly an independent consultant for several different firms, including Seaway Networks, Potentia, and Quake. MRF

▸SHORT COURSES

Microwave Antenna Measurements Short Course: Far-Field, Near-Field, Compact Ranges, and Anechoic Chambers
June 15-18 (Northridge, CA)
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Michelle Manchester or Debby Schneider
(818) 677-2146, FAX: (818) 677-5982
e-mail: michelle.manchester@csun.edu or debby@csun.edu
Internet: www.ecs.csun.edu/~crs/mam/

R.A. Wood Short Courses
RF Power Amplifiers, Classes A-S: How the Circuits Operate, How To Design Them, & When To Use Each
June 21-22 (Cleveland, OH)
September 20-21 (Syracuse, NY)
November 8-9 (Philadelphia, PA)
Wireless Engineering—For Designers
June 14-18 (Cleveland, OH)
September 13-17 (Syracuse, NY)
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Introductory RF and Microwaves
June 21-22 (Cleveland, OH)
September 20-21 (Syracuse, NY)
November 8-9 (Philadelphia, PA)
RF and Microwave Receiver Design
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September 22-24 (Syracuse, NY)
November 10-12 (Philadelphia, PA)
For further information, see:
www.rawood.com/seminars
For a PDF course brochure, see:
www.rawood.com/ftp_files/course_brochure_2003-3.pdf

CMOS Analog Integrated Circuits
August 2-6 (Atlanta, GA)
For further information, contact:
Georgia Institute of Technology
Professional Education—R
P.O. Box 93686
Atlanta, GA 30377-0686
(404) 385-3500, FAX: (404) 894-8925
Internet: www.pe.gatech.edu — KEYWORD: CMOS

▸MEETINGS

Precision Micro Machining Technology and Applications
May 26-27 (Springfield, MA)
Marriot Springfield
For further information, contact:
SME
P.O. Box 6028
Dearborn, MI 48121
(800) 733-4763
Internet: www.sme.org/micro

41st Design Automation Conference
June 7-11 (San Diego, CA)
San Diego Convention Center
(800) 321-4573
Internet: www.dac.com

Wi-Fi Planet Conference & Expo
June 8-10 (Baltimore, MD)
Baltimore Convention Center
For details on exhibiting or for sponsorship opportunities, e-mail wifiplanet@jupitermedia.com or call (203) 662-2822
For registration questions, contact registration@jupitermedia.com or call (203) 662-2857
Internet: www.jupiterevents.com

63rd ARFTG Microwave Measurements Conference: On-Wafer Characterization
June 11 (Fort Worth, TX)
Fort Worth Convention Center
Internet: www.arftg.org

ASTM 14th International Symposium on Zirconium
June 13-17 (Stockholm, Sweden)
City Conference Centre, Norra Latin
Sponsored by the ASTM Committee B10 on Reactive and Refractive Metals and Alloys
Internet:
www.astm.org/SYMPOSIA/B10_Symp.htm

2004 Symposium on VLSI Technology
June 15-17 (Honolulu, HI)
Hilton Hawaiian Village
e-mail: vlsi@vlsisymposium.org
Internet: www.vlsisymposium.org

37th Annual IICIT Connector & Interconnection Technology Symposium & Trade Show
September 13-15 (Dearborn, MI)
Hyatt Regency Dearborn
Internet: www.iicit.org

ASTM Committee B02 on Nonferrous Metals and Alloys
November 8-10 (Washington, DC)
For further information, contact Jeffrey Adkins, ASTM — (610) 832-9738
e-mail: jadkins@astm.org
Internet: www.astm.org/COMMIT/B02.htm

electronica 2004
November 9-12 (Munich, Germany)
New Munich Trade Fair Centre
Randi M. West, (312) 377-2650
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ASTM Committee B10 on Reactive and Refractory Metals and Alloys
November 10-11 (Washington, DC)
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e-mail: jadkins@astm.org
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▸CALL FOR PAPERS

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Stacked Square MSAs Serve VICS

COMMUNICATIONS BETWEEN VEHICLES and roadside beacons can enhance traffic safety and improve the flow of traffic. For this application, Takafumi Fujimoto and associates from the Department of Electrical Engineering of Nagasaki University (Nagasaki, Japan) have developed a new approach to the rectangular microstrip antenna (MSA) traditionally used for this purpose. Their stacked square MSA with a shorting post is designed for the vehicle information and communication system (VICS), in which the car-mounted antenna receives information from a beacon antenna mounted along the shoulder of the road.

The researchers used version 9.0 of the IE3D electromagnetic (EM) simulation software from Zeland Software (Fremont, CA). The software, which is based on the use of the method of moments (MoM) in the spectral domain, was used for analyzing the performance of stacked MSAs.

The stacked MSA was designed for the VICS center frequency of 2.49997 GHz and bandwidth of 85 kHz. The antenna was modeled for and fabricated on a substrate material with dielectric constant of 2.6 and thickness of 2.4 mm. To evaluate the vehicular antenna, an array antenna of two cirrcular MSAs was used as the beacon antenna and the effective directivity of the vehicular antenna was evaluated. Although the return-loss performance of the stacked MSA was comparable to conventional rectangular MSAs used for this purpose, it is a fraction of the size of a conventional microstrip vehicular antenna at that frequency (2.5 GHz), with consistent radiation patterns within the communications area modeled for the VICS. See "Stacked Square Microstrip Antenna With a Shoring Post for Road-Vehicle Communication," *RF and Microwave Computer-Aided Engineering,* Vol. 14, No. 3, May 2004, pp. 244-252

Evaluating 20-GHz Rainfall Attenuation

RELIABLE COMMUNICATIONS in tropical regions requires knowledge of rain-induced attenuation. Established models of rain-induced attenuation, such as the International Telecommunications Union (ITU) models, are typically used in temperate climates with fairly good accuracy. But when these same models are applied to regions with heavy rainfall, they provide unsatisfactory results. Because of this, Ashok Kumar and fellow researchers with the Department of Electronics Technology at Guru Nanak Dev University (Amritsar, India) set out to gather as much information as they could from a 19.9-GHz Dicke-switched superheterodyne radiometer with 24-in. vertically polarized front-fed parabolic antenna. The radiometer, which measures the sky temperature across an RF bandwidth of 2 GHz, works with a hot reference source at 373 K and a cold reference source at 77.4 K; the radiometer's Dicke switch was continuously switched at a rate of 1 kHz. The radiometer and antenna assembly were mounted on an azimuth and elevation steerable stand to align them at zenith, and housed in an air-conditioned hut. Layers of acrylic sheets were placed in front of the antenna to minimize changes in the effective system noise temperature. The radiometer, which is located in a rain climate, was used to measure attenuation during the mots of July and August, in which total rain accumulation was 411 mm. See "Measurement of Rain-Induced Zenith-Path Attenuation Using 19.9 GHz Radiometer at Amritsar (India)." *IEEE Transactions on Antennas and Propagation, Journal of EMC,* 1999 edition, Vol. 52, No. 3, March 2004, pp. 702-708.

Generating Signals For Radio-Over-Fiber Systems

RADIO-OVER-FIBER technology using single-mode optical fibers has been proposed as a means of transferring wideband RF signals between remote access units (RAUs). But the cost of generating the high carrier signals needed for these networks (include 60 GHz) can be prohibitive, leading Anthony Ng'omo and associates from the COBRA Institute of the Eindhoven University of Technology (Eindhoven, The Netherlands) to explore a novel method of optical frequency multiplication that can be used to deliver high-frequency modulated carriers to RAUs. The system downlink involves the preprocessing of optical signals at a centralized headend by sweeping the optical frequency with a tunable or frequency-modulated laser source. The system was used to generate modulation bandwidths from 20 to 60 MHz, but offered the capability of bandwidths to 100 MHz. See "Frequency Up-Conversion in Multimode Fiber-Fed Broadband Wireless Networks by Using Agile Tunable Laser Source," *Microwave and Optical Technology Letters,* Vol. 41, No. 1, April 5, 2004, pp. 28-30.

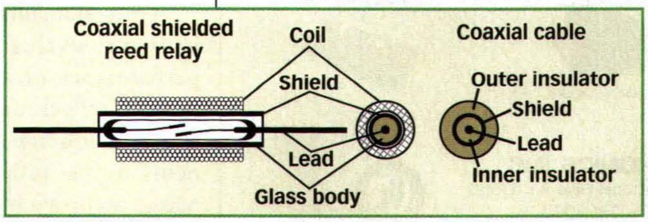
Characterizing Reed Relays Past 7 GHz

Surface-mount reed relays offer distortion-free performance in high-frequency circuits past 7 GHz, with characteristics well suited to both analog and digital signal processing.

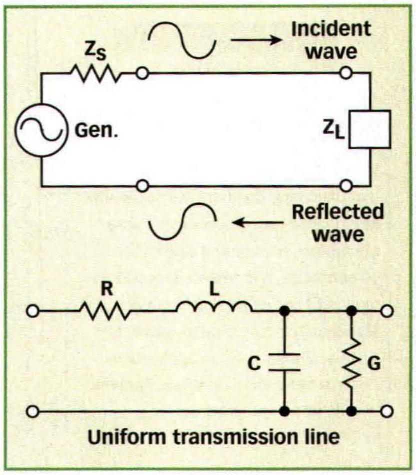
JOHN BEIGEL
Chief Executive Officer
MEDER Electronic US, P.O. Box 2207, Mashpee, MA 02649; (800) 870-5385, (508) 539-0002, FAX: (508) 539-4088, Internet: www.meder.com.

Applications for RF components continue to grow, not only in traditional military markets, but in commercial, industrial, medical, and automotive applications. With the rising frequencies of analog signals and increasing speeds of digital signals comes the need to switch these signals along different transmission paths. While GaAs-based switches have handled high-speed signals for many years, there is now another component option for switching fast signals through 10 GHz: the reed relay.

In its geometry, a reed relay resembles a coaxial cable **(Fig. 1)**. The magnetic reeds make up the center conductor with a glass envelope setting the spacing from the center conductor to the coaxial shield, and establishing the characteristic impedance (typically 50 Ω). Early reed relays were large and not considered for RF applications. But as designs began to shrink in the 1980s, their signal paths decreased to dimensions that were more practical for the short wavelengths of RF signals. During this period, the all-important signal-to-shield capacitance began to drop below 1.0 pF and the RF performance improved. In modern reed relays with reed switch lengths of 5 mm or less, the signal-to-shield capacitance has dropped to 0.5 pF when the reed is in the open state **(Fig. 2)**.

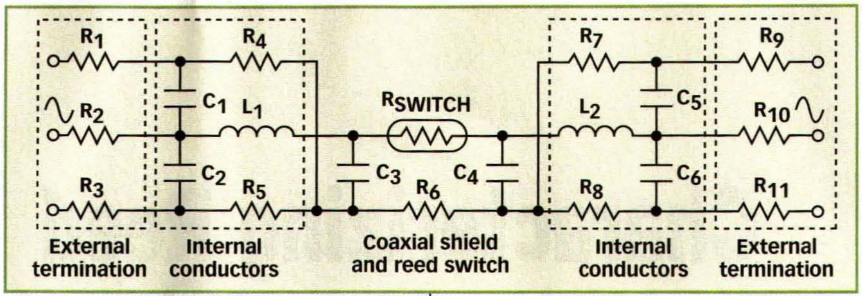


1. A reed relay with a coaxial shield is similar to an RF transmission line. Since the coil is effectively screened by the coaxial shield, it has no effect on the transmission of RF signals along the center lead conductor.



2. A transmission line can be modeled as a series impedance, which causes reflections from incident, waves (top). At any point in a transmission line, an incident signal sees a combination of effective circuit elements (bottom).

By their nature, reed relays do not suffer the intermodulation distortion (IMD) common to high-frequency electronic switches. The 3-dB bandwidth of reed relays in the CRF series from MEDER Electronic (Mashpee, MA) is currently DC to 7 GHz and rising. Form



3. This equivalent circuit represents the closed contacts of a coaxial shielded reed relay with two ground terminals on both the input and output of the relay.

C (single-pole, double-throw) reed relays require no external power in their normally closed state, making them well suited for critical low-power applications.

In test and measurement, particularly integrated-circuit (IC) testers and wafer testers, with parallel high switch point counts, leakage current becomes a real problem. Reed relays designed to handle fast digital pulses will exhibit extremely low leakage currents on the order of 0.1 pA or less. No other technology currently offers anything close to this combination.

S-parameters, which represent the magnitude and phase of incident and reflected signals through a component, provide a suitable means of measuring and modeling reed relays. Using a vector network analyzer (VNA), it is possible to characterize the frequency-domain performance of a reed relay at microwave frequencies, and then develop equivalent-circuit models such as those shown in **Figs. 3 and 4.** By using the S-parameter representations of a reed relay in a computer-aided-engineering (CAE) software program, an engineer can study how the reed relay will interact with other components in a high-frequency circuit.

A time-domain reflectometer (TDR) is used to evaluate the time-domain performance of a reed relay. Time-domain reflectometry characterizes a transmission line or series of components by the reflections or discontinuities occurring from a pulse of known amplitude and rise time traveling through the line or components. A transmission line terminated in its characteristic impedance appears as

an infinitely long line (with no reflections). A transmission line with no termination (an open circuit) causes reflections due to impedance mismatches. Detection of relative position of discontinuities, whether inductive or capacitive, depends upon the polarity of the reflected signal. However, by knowing the polarity of the reflection, it is possible to redesign a component to eliminate that capacitive or inductive point and yield smoother signal-transmission characteristics.

In time-domain characterization, rise time is a key parameter for determining a component's effects on signal fidelity. Rise time is usually defined as the time between 10 and 90 percent of the full amplitude of the leading edge of a pulse (although values of 20 and 80 percent are also used). A pulse incident upon a relay with a perfect rise time (0 ps) will be altered once it exits the relay with a rise time stated as the relay rise time. Any system dealing with fast digital pulses must consider the rise time through the components where rounding off and/or distortion of the square wave can occur.

The characteristic impedance represents the distributed impedance at any instantaneous point at the entry, through and exiting the relay. A pulse or signal traveling through the path of the relay seeing any impedance changes will reflect some of its signal strength. Standing waves can occur at these reflection points.

The mechanical features that make reed relays attractive for many designs include the following:

1. Small size.
2. Minimum path length improving the RF and fast digital pulse characteristics.
3. Gold-plated signal path for high conductivity and minimizing any RF loss.
4. No lead frame design eliminating any skewing of leads and coplanarity issues.
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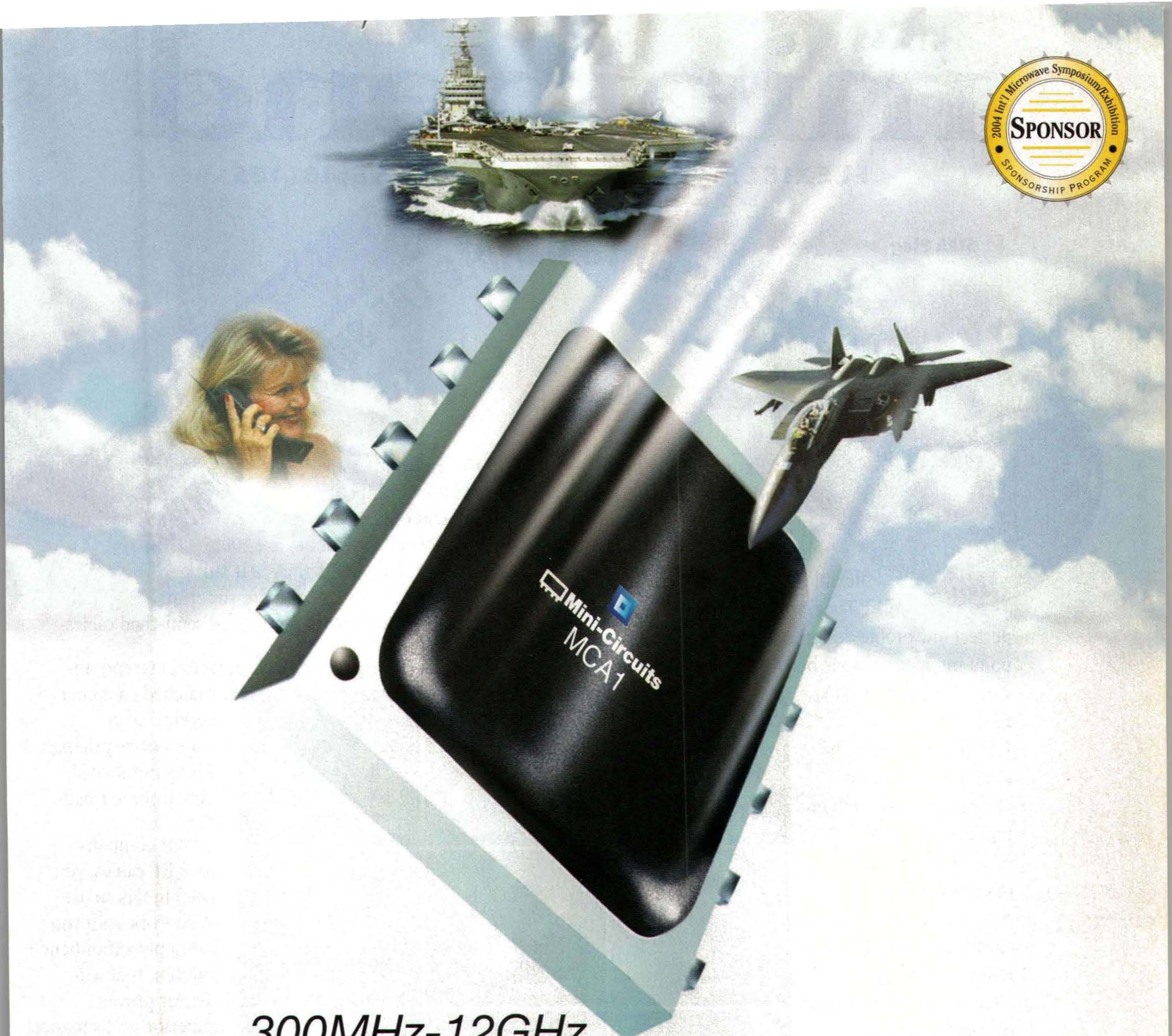
6. Internal magnetic shield, eliminating



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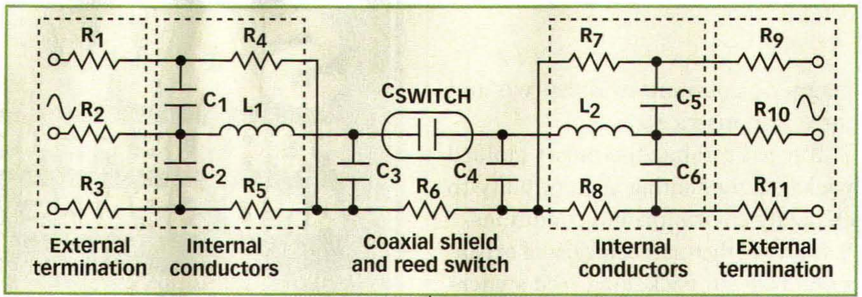
A reed relay's electrical features include:
1. Capability of switching and passing 7 GHz and higher frequencies.
2. Capability of passing digital pulses in the order of 40 ps without degradation of leading and trailing edges.
3. Characteristic impedance of 50 W.
4. Low switch-to-shield capacitance (0.7 pF).
5. High insulation resistance between all points typically greater than 10^{14} W.
6. Thermal offset voltages of typically less than 1 µV.
7. Input (coil and shield) to output (switch) dielectric strength of 1500 VDC minimum.

Miniature reed relays are well suited for a variety of applications, including in integrated circuit testers, wafer testers, functional PCB testers, the front ends of multimeters where low voltage offsets of less than 1 µV and leakage current of less than 1 pA are required, in feedback loops where high-frequency, low leakage, and high voltage isolation are a requirement, for high-speed switching in oscilloscopes, for high-frequency attenuators, in portable devices such as cellular telephones, pagers, and PDAs, and for transmitter/receiver switching.

Most important in the testing of any component for frequency response over 100 MHz is a good vector network analyzer (VNA) and carefully designed test fixtures for calibration as well as for the actual testing. The same is true when testing in the time domain. In the time domain, when measuring rise-time characteristics, one must be aware of overshoot and undershoot of the rise time pulse that may compromise measure-

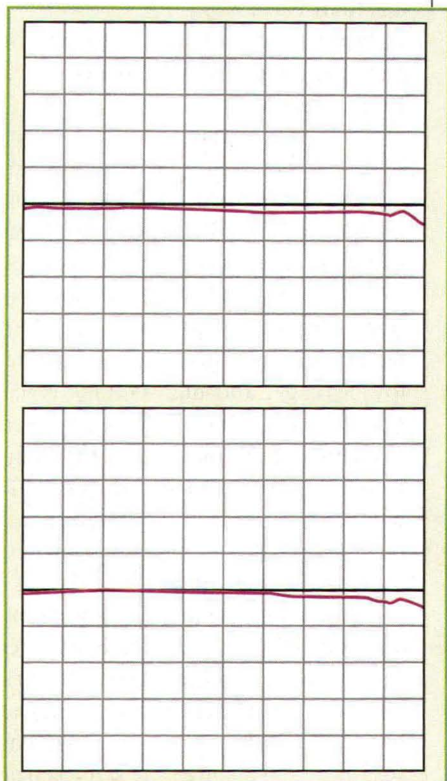
ments. These overshoots or undershoots if real, may compromise the components function in actual test systems. Care must be taken to determine whether this phenomena is real or related to the fixture. Fixture design starts with suitable SMA connectors on high-frequency



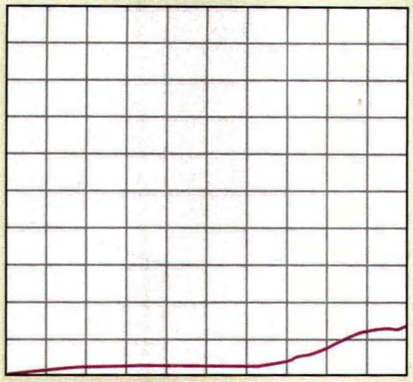
4. This equivalent circuit represents the open contacts of a coaxial shielded reed relay with two ground terminals on both the input and output of the relay.

printed-circuit-board (PCB) material. Several PCB materials are suitable for this application, including FR-4, G-10, and several material products from Rogers Corp. (Rogers, CT).

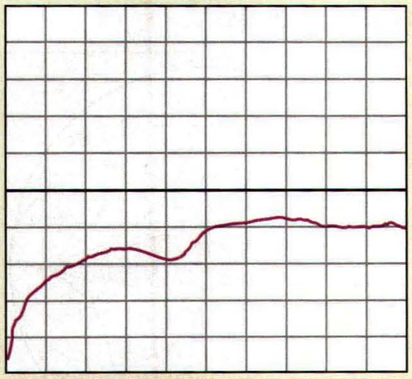
Many engineers feel that FR-4 material is suitable for such testing since the fixture zeroing process will eliminate its high-frequency loss characteristics. As a general rule, the use of FR-4 below 6 GHz is fine, but above 6 GHz the use of high-frequency circuit materials such as RO3203 or RO4350 from Rogers



5. Insertion loss was tested for the standard reed relay (top) and then for a modified version in which the internal reed switch was replaced with a bare copper wire (bottom).



6. The VSWR of the reed relay was tested through frequencies to 6.5 GHz.



7. The isolation of the reed relay is about 50 dB at lower frequencies, dropping to about 10 dB at the higher frequencies.

Corp. will improve test performance. Rogers has several other materials available depending upon the TCE matching of the component/s or performance requirements. Most of these materials are ceramic filled.

Calibration boards were created for a variety of conditions, including shorted to ground, open-circuit, and a through-line circuit. As many ground points as possible were used along with avoiding and sharp corners. The electrical contributions of all calibration boards were measured and stored in the memory of a model 8720ES VNA from Agilent Technologies (Santa Rosa, CA). The relay under test (RUT) was then measured and its characteristics stored in the VNA's memory. The calibration data was then entered and the losses due to the calibration board under the various configurations was extracted, yielding the results shown in **Figs. 5 through 9**. This was compared with data extracted using the MIMICAD CAE program from Optotek Ltd. (Kanata, Ontario, Canada) using the equivalent circuit presented and the S parameters, with measured and modeled results agreeing closely.

The test fixtures used for evaluating the reed relays doubled as calibration boards. All of the fixture boards used to test the RUTs used SMA connectors for connection to and from the test equipment and for terminations. The following are the makeup of the boards under test:

1. The RUT calibrated with a 50-Ω line and open termination.
2. The RUT calibrated with a 50-Ω line and shorted termination.
3. The RUT calibrated with a 50-Ω line and 50-Ω termination.
4. The RUT calibrated with a 50-Ω line through line.

The fixtures were made from FR-4 PCB material. The use of higher-performance PCB materials may improve the results shown in Figs. 5 through 9.

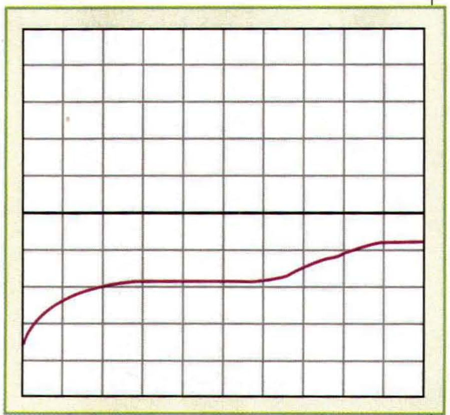
Insertion loss is the loss of power going through the relay. Insertion loss is one of the most important RF measurements because it is simply a measure of the loss of the signal going through the component (reed relay). Minimizing this loss is a key interest for most applications. For the RUT, insertion loss is minimal to 7 GHz (**Fig. 5**, top). Clearly, signals, whether digital or analog, will fare very well when switched and passing through this CRF ceramic reed relay. When using semiconductors as a switching element, IMD may occur, giving rise to distortion in the frequency response. With a passive device such as the reed relay, IMD is nonexistent, resulting in flat insertion loss to 7 GHz. This flat insertion loss allows a user to switch and transfer a multitude of different frequencies or different-width digital pulses without using a variety of switches for different frequency bands.

At higher frequencies, it has been proposed that a reed relay, because it uses nickel/iron as its center conductor,

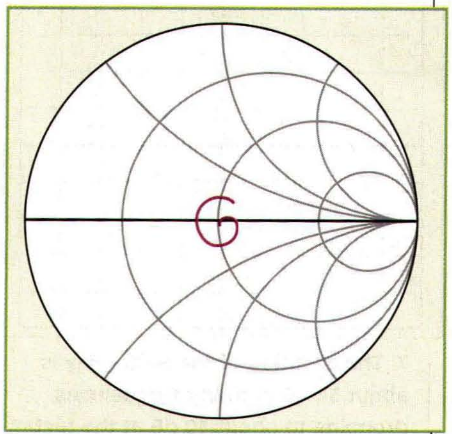
will not have very good performance characteristics. Skin effect is often the proposed culprit, because nickel and iron, being ferromagnetic, have a high magnetic permeability (μ). However, as Fig. 5 (bottom) indicates, this is not the case. When a pure copper wire replaces the reed switch, there is little or no difference in insertion-loss performance. Under high-power conditions, some differences may be noticeable, but for most lower-power applications, the reed relays provide transmission-line-like performance through 7 GHz.

VSWR represents the effects of the transmission of power due to standing waves. When standing waves are present on a line, some power is being reflected back on the line and re-reflecting again from the source. This back and forth reflection produces standing waves. These standing waves interfere with the transmission of the original signals from the source because they are continuously present and continually absorb power. **Figure 6** shows the reed relay's VSWR performance. While still an important RF characteristic for analog CW analysis, insertion loss is considered more critical for RF applications.

Isolation is the ability of a component to isolate the RF signal from propagating further in a circuit. For a reed relay, the isolation is a measure of the ability to halt further progress of the signal when it is in the open state. Of course, given RF energy, an open circuit is not totally open because the capacitance across the contacts represents a leakage path; with high enough frequencies, that's exactly what occurs. **Figure 7** shows isolation of 50 dB or more at low frequencies, dropping to 15 dB at 3 GHz and at least 10 dB at 7 GHz. Contributing to this drop off in isolation is the contact gap. Increasing the gap on the reed switch is very difficult to do because it would require a larger capsule, which would increase the package size. Also, a larger gap will make the switch less sensitive for closure, requiring more coil power. If



8. The return loss of the reed relay is an impressive 35 dB at low frequencies, dropping to about 10 dB at the higher frequencies.



9. This Smith Chart shows the impedance of the reed relay plotted from 50 kHz to 4 GHz.

the isolation is a critical parameter in an application, stringing more than one Reed Relay together will help. Also using a 'T' switch or half 'T' switch will yield much higher isolations.

Figure 8 shows reed relay return loss, a measure of the power of the RF signal being reflected back to the source (with the larger value in dB representing a smaller percentage of reflected signal). The return loss has only 35 dB of the reflected signal at the lower frequencies and about 10 dB reflected signal at 6.5 GHz.

Characteristic-impedance measurements (not shown) on the reed relay were performed by checking a signal at certain points along the relay. Since this measurement is a spatial measurement, the actual impedance

at each point of the relay can be measured. The relay was found to be slightly above 50 Ω, indicating a slightly inductive entrance into and out of the relay. Compensating with a little capacitance on each end of the relay will tune the impedance to the desired level. This will, in turn, improve the performance of the relay in a given circuit and increase its performance at higher RF frequencies as well.

Plotting a reed relay's S–parameters on a Smith Chart shows the characteristic impedance over a given frequency range. The Smith Chart of **Fig. 9** presents a plot of the response of frequencies every 50 kHz up to 4 GHz with points centered around the 50-Ω real point. To better understand this Smith Chart, the second dotted circle starting from the right center point of the large circle is the 50-Ω impedance circle. The centerline of the circle, which is running horizontally, is the real axis. Plots above this line are inductive while plots below this line are capacitive. The plot of the CRF relay is in a tight circle around the real axis, and centered around the 50-Ω circular axis. If tuning is necessary for a particular frequency, an engineer will know whether capacitance or inductance must be added to further improve performance.

As is evident from the data presented, the CRF reed relay is excellent for switching and carrying RF signals to 7 GHz and beyond. Current efforts are underway to improve the design's characteristics up to 10 GHz and beyond, part of an ongoing effort to continually develop new RF relays, pushing the current bandwidth and current state of the art. As higher and higher frequencies are used and components are needed to develop these circuits, the need for reed relays like the CRF series and subsequent improvements on performance over existing data will be needed. MRF

Understanding Digital Signal Processing

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DIGITAL SIGNAL PROCESSING (DSP) is one of the most essential technologies in both commercial and military communications systems. DSP, for example, allows near-ideal filters to be defined in order to receive complex modulation formats, such as code-division-multiple-access (CDMA) cellular communications. Fortunately, *Understanding Digital Signal Processing* by Richard Lyons provides a thorough introduction to this important technology, covering a large sampling of the many functions that can be implemented for communications systems by means of DSP technology. In the second edition of his popular text (the first edition was published in 1997), Lyons has augmented his coverage of DSP and digital filters by expanding his treatment of complex in-phase/quadrature (I/Q) signals common to digital modulation formats, revised his terminology to be consistent with other publications covering DSP, added discussions on interpolated finite-impulse-response (FIR) filters, and added material on the Hilbert transform and how it can be applied to processing quadrature signals.

Lyons prefaces his text with the encluraging statement that learning the fundamentals of DSP is not difficult, but has gotten a reputation for being challenging because of the lack of organization of educational materials about DSP. He has chosen to minimize the use of mathematical formulae in favor of text explanations of complex functions and sampling theory in the hopes of making the learning of DSP technology a bit less daunting to his readers.

The book's 13 chapters cover such topics as periodic sampling, the discrete Fourier transform, FIR filters, infinite impulse response (IIR) filters, sample-rate conversions, signal averaging, and DSP tracks. A total of eight Appendix sections offer details on the arithmetic of complex numbers, standard deviations (along with means and variances), sampling filter tables, and digital filter terminology.

For those with limited math brackground, *Understanding Digital Signal Processing* nonetheless offers an accessible journey into the world of DSP technology. Even by reading the first six chapters, an engineer or marketing specialist can receive a usable background on the essentials of DSP and the FIR and IIR filters common to many modern communications systems. (ISBN: 0-13-108989-7, 2004, hardcover, 665 pages, $79.99.) **Addison-Wesley Professional/Prentice-Hall PTR, One Lake St., Upper Saddle River, NJ 07458; (201) 236-7139, FAX: (201) 236-7123, e-mail: heather.fox@pearsoned.com, Internet: www.phptr.com or www.awprofessional.com.**

Consider Antenna Options For Minimal Interference

Understanding the effects of radomes can go a long way in optimizing a microwave link budget and maximizing the performance of a given microwave antenna system.

DR. DANIEL WOJTKOWIAK
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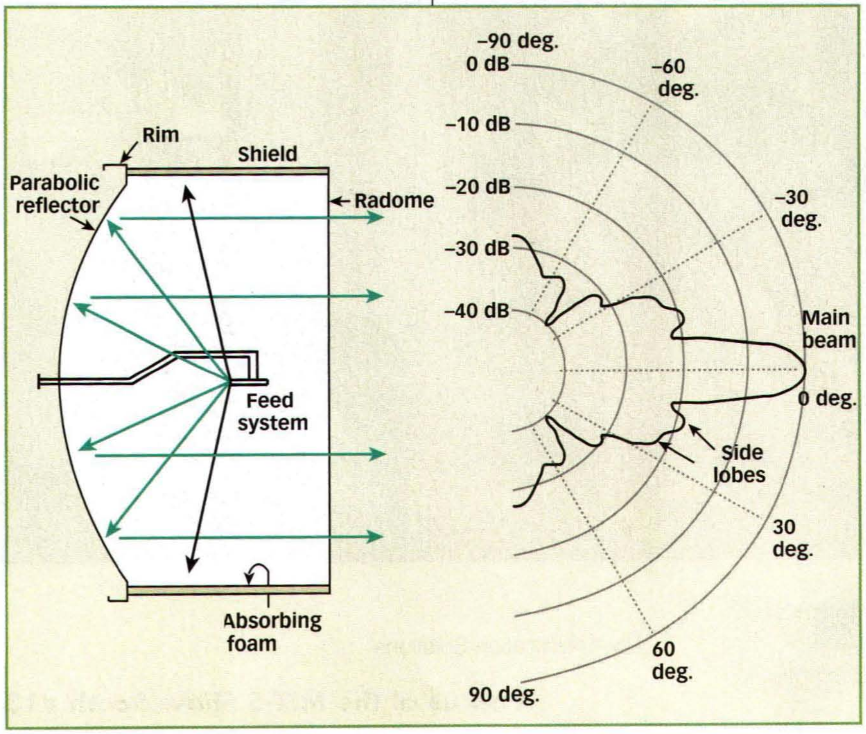
Microwave links provide invaluable "free-space" networking for the telecommunications industry. The relative ease and economy of installation has seen them deployed in an increasing number of point-to-point and point-to-multipoint applications—from communications backbones, to branch links and distribution networks, not to mention applications in the broadcast industry and private enterprise. With the rise of new cellular operators and new technologies, overall microwave network density is undeniably escalating.

Yet this intensification of microwave communications brings added challenge. The greater the number of point-to-point links in a given area, the greater the potential for these microwave systems to interact with one another and cause interference. Since any signal distortion reduces the quality of ser-



1. A typical microwave antenna system with parabolic reflector, shield, and radome will yield a strong main signal and lower-level side-lobe signals.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vice (QoS), controlling interference is now the mandate of any radio network operator and national authority. A good starting point for consideration is the design and location of the source of the signal—the microwave antenna (**Fig. 1**). **Figure 2** shows a typical radiation pattern of a microwave antenna, with the main beam at 0 deg. and sidelobes that are significant to about ±90 deg. from the main beam. It is these sidelobes, which can cause interference with adjacent point-to-point links, that must be minimized through careful antenna design and installation.

Radomes are used for two main applications in radio-link antenna design. The first is for environmental protection, to cover the antenna feed system in order to protect it from dirt, snow, and ice. In addition, a radome significantly reduces the windload of an antenna system. However, both material selection and thickness need to be carefully considered to optimize the power transmitted through a radome, while at the same time ensuring that sidelobes are not increased.

Figure 3 shows the reflection characteristics of a plane-wall radome for different materials. Each of these materials is characterized by a relative dielectric constant of $\epsilon_r = 2$; however, each material has a different loss parameter, tan δ, ranging from 0.0018 (low loss) to 18 (high loss). Figure 3 shows that for low-loss materials, there exists two distinct minimum values of the reflection coefficient, for which a radome wall will allow maximum transmission of incident power. These correspond to design values where the ratio of radome wall thickness (d) to microwave wavelength in the sheet (λ) is close to either zero or 0.5.

The first case of $d/\lambda \approx 0$ is practically realized as $d < \lambda/10$, and leads to flexible radome materials with typical thicknesses of 0.4 to 0.6 mm—essentially as thin as is practical. Flexible radomes are commonly used for larger antennas (greater than 4 ft.), to avoid the bulk and weight of solid radomes.

The second design case of $d/\lambda \approx 0.5$ is more complex, and leads to the design of solid radomes, which are more economical to produce at smaller sizes (less than 6 ft.). The practical implication of $d \approx \lambda/2$ is that the thickness of solid radomes is always dependent on the wavelength (hence frequency) of the application. Assuming a dielectric constant between 2.5 and 3, typical solid radome thicknesses for different frequencies would be 6 mm (14 GHz), 4 mm (22 GHz), and 2.4 mm (38 GHz).

This effect of frequency on solid radome design is illustrated in **Fig. 4**, which shows return-loss measurements over

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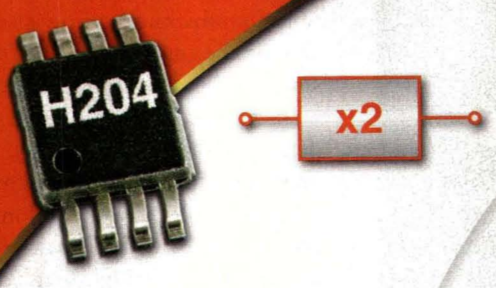

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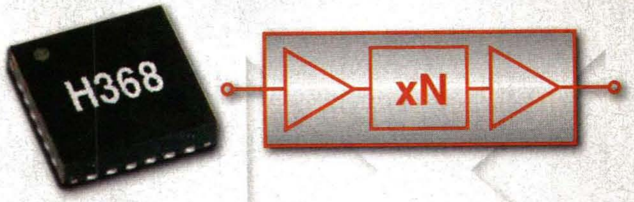

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a range of frequencies for an antenna designed to operate at 23 GHz. The red curve is the calculated difference between the separate curves for the antenna with and without the radome: clearly, the minimum difference—corresponding to the minimum impact of the radome at $d \approx \lambda/2$—occurs at a design frequency of 22.6 GHz.

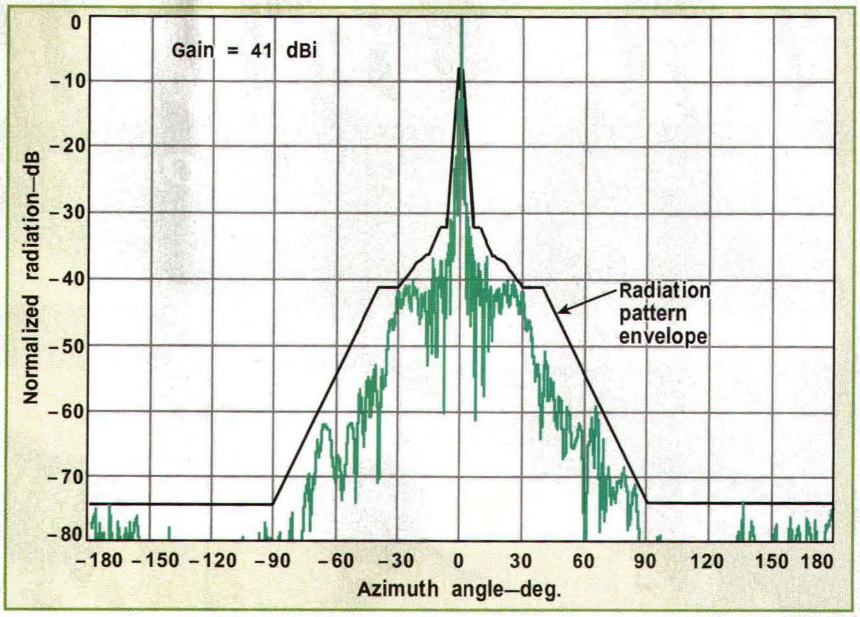
If a radome of incorrect thickness is used, the transmitted power will be reduced, and consequently the antenna gain also reduced. Greater radio power would then be required to achieve the desired radiated power, resulting in a corresponding increase of side-lobe radiation. Correct radome design is critical not only for optimizing a link budget, but also for interference control.

Figure 3 is valid for the "ideal" case, where wave fronts hit the wall perpendicularly. Now consider the situation for signals not having this ideal orientation. Given the longer effective wave path through the radome material as they hit the wall obliquely, the optimum thickness is now also dependent on the angle of incidence (θ), measured as the deviation from normal.

In practice, however, angles of incidence to 20 deg. have negligible effect on the optimum radome thickness. This is illustrated for flexible radome materials in **Fig. 5**, which shows the relationship between angle of incidence (θ) and d/λ_o (where λ_o is the free-space wavelength), for achieving 95 percent power transmission through materials with different dielectric constants. For values of θ to 20 deg., the optimum thickness is barely impacted—particularly for low-loss materials, which should be those considered for radome design purposes.

A similar relationship holds for solid radomes. These relationships have been exploited in practical fashion by many microwave antenna designers. A small degree of tilt of the main beam—around 5 deg.—actually *improves* the performance of the antenna, by directing spurious reflections within the antenna away from the microwave feed system.

The influence of typical thin wall or flexible radomes can be seen in **Fig. 6**, which compares the radiation patterns of microwave antennas operating with and without radomes at 6.4 and 33.4 GHz. At 6.4 GHz, it is evident the radome has negligible effect on the radiation pattern. However, at 33.4 GHz the gain of the antenna is decreased by 1 dB due to attenuation by the radome. Once again, to achieve the same link budget the transmitted power must be increased by 1 dB, causing a higher interference potential outside the main beam. The presence of the radome also leads to increased side lobe levels, clear-



2. This radiation pattern is typical for a microwave antenna, with side-lobe signals being generated at significant levels at azimuth angles out to ±90 deg.

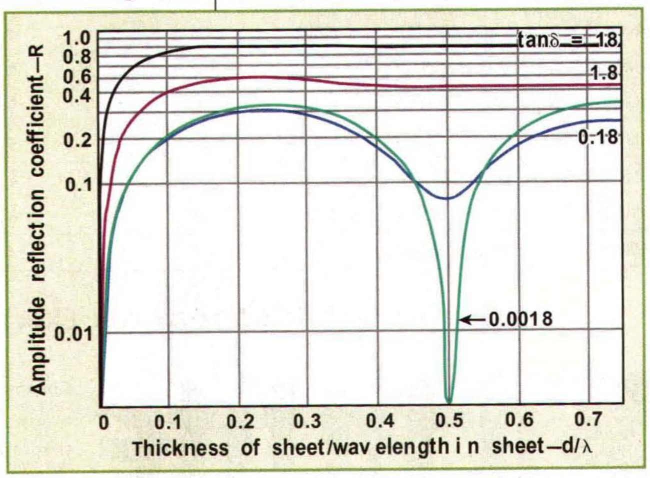
ly visible in Fig. 6 at azimuth angles between 20 and 60 deg.

This effect of the radome on the 33.4-GHz antenna is due to the fact that, at higher frequencies, flexible radome design becomes more sensitive to the practical constraints on material thickness and stability. Whereas the design ratio of $d/\lambda \approx 0.01$ can be achieved for the 6.4-GHz antenna, the best possible case for the 33.4-GHz antenna is just $d/\lambda \approx 0.05$, which is not as close to the ideal zero.

No matter how carefully a microwave antenna radome is designed, the potential increase in side lobes remains. This must be taken into account during other aspects of design and installation of the antenna to minimize interference.

The basic "standard-performance" microwave antenna consists of an open dish and a feed system. Usually lacking a radome (although a molded radome is an option), standard performance antennas are economical solutions for specific applications. Aside from the lack of environmental protection of the feed system, the main drawback is the diffraction of microwave energy at the rim of the dish; these result in significant backward reflections at azimuth angles of ±100 deg., which can interfere with adjacent point-to-point links.

To block these backward rim reflections, antenna designers place a shield around the circumference of the antenna, to which a planar radome is usually attached **(Fig. 7)**. These "high-performance" microwave antennas may be further enhanced by the application of absorbing foam to the inside of the shield, resulting in "ultra-high-perfor-

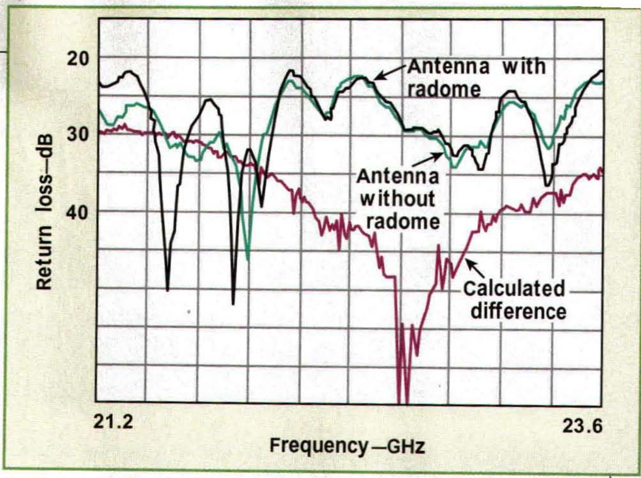


3. The reflection characteristics at a plane-wall radome are shown as a function of sheet thickness.

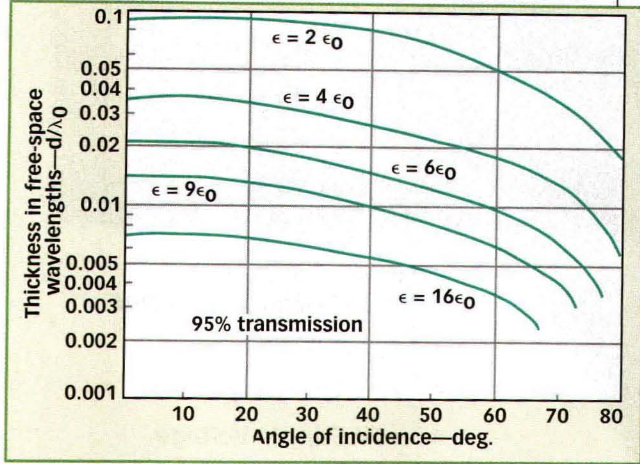
mance" microwave antennas. The foam absorbs spurious reflections within the antenna and improves performance through limiting the side lobes.

Radiation pattern envelopes for standard, high, and ultra-high-performance antennas are compared in **Fig. 8.** The improvement in side-lobe reflection control of the ultra-high-performance antenna over both other antennas is evident. Interestingly though, the high-performance antenna exhibits poorer performance than the standard performance antenna between 20 and 60 deg.—the result of additional reflections off the shield. It nevertheless proves significantly better at preventing backward reflections. Selection of the appropriate microwave antenna depends on the intended application, and the expected interference potential in a given area.

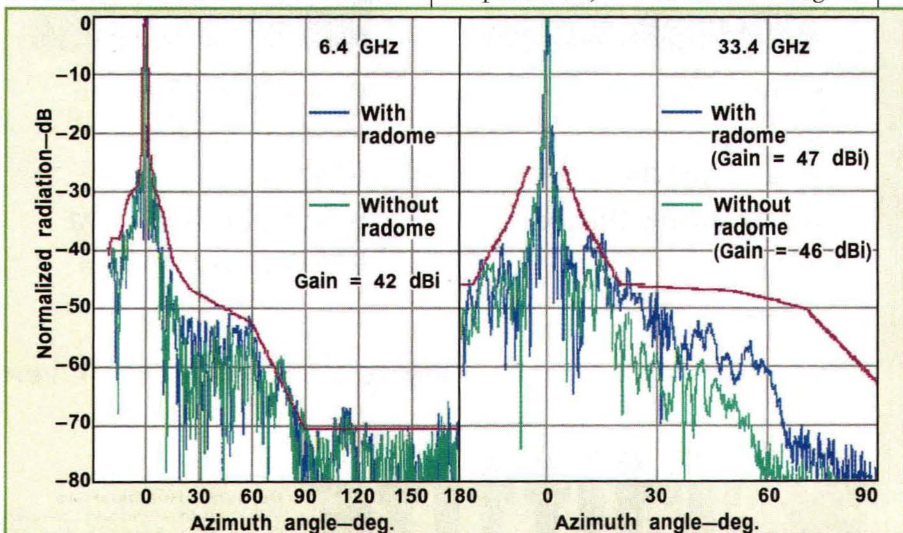
It is important that, once installed, the performance of a microwave network should not deteriorate due to environmental impact. While a radome might protect the sensitive feed system from the elements, only a stable construction can protect the dish from wind. Mechanical stability of an installed antenna is critical to maintain a point-to-point link, as well as restricting its



4. A microwave antenna with and without a radome was evaluated at a center frequency of about 22.4 GHz.



5. Flexible radome design depends on incidence angle.



6. These displays show the effects of flexible radomes on antenna performance at 6.4 and 33.4 GHz.

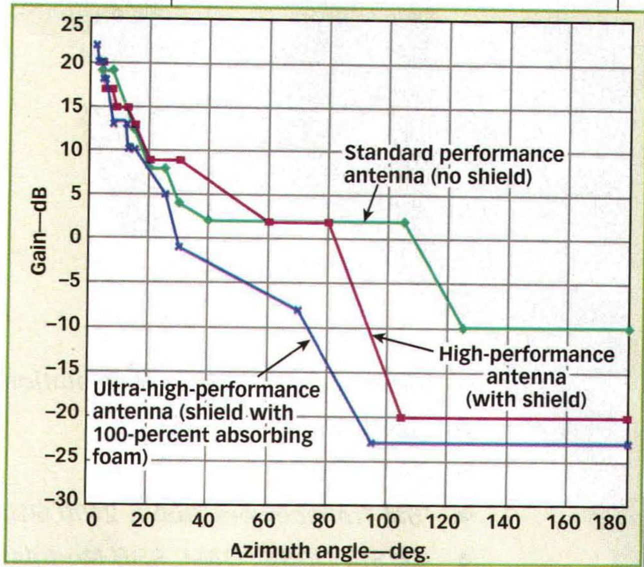
potential for interference with adjacent links, if its orientation changes.

Different antenna manufacturers use different methods of rating the antenna resistance to wind. Radio Frequency Systems defines the "operational wind speed" rating of an installed antenna as that for which temporary deflection of the main beam is within one-third of the half-power beam width of the antenna. (The half-power beam width is defined as the angle, relative to the main beam axis, between the two directions at which the measured co-polar pattern is 3 dB below the value on the main beam axis.) Within this operational wind speed—of which typical values are 120 to 140 mph—the point-to-point link will be satisfactorily maintained.

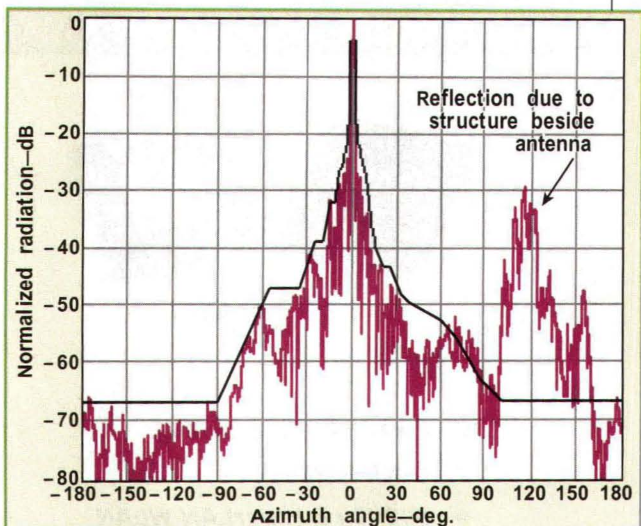
Other standards consider the operational wind speed as that for which the main beam is not deviated by more than 0.1 deg. Whatever the method used, it is important to take the deflection of the mounting structure into consideration during calculation of the beam deflection.

The positional mounting of antennas must also be considered by operators seeking to minimize interference. Typical multi-antenna tower installations exhibit interference, and even the mounting structure may directly impact the performance of the microwave link through shielding and the generation of reflections from outside of the antenna itself. This is particularly the case when antennas are mounted on the face of buildings and solid towers, while **Fig. 9** shows the significant reflections that arise when an antenna is mounted too close to a solid structure to the side. Such structure-generated reflections are likely sources of interference, and are often not taken into consideration during installation.


7. Typical high-performance microwave antennas incorporate shields and absorbing materials to minimize side-lobe radiation.



8. These curves compare the performance levels of standard, high-, and ultra-high-performance antennas.



9. This plot shows that significant reflections may arise when an antenna is mounted too close to a solid structure.

Estimate Multiple Carrier Interference

By some simple relationships, the third-order intercept point can be used to calculate interference due to the mixing of multiple carriers in a communications channel.

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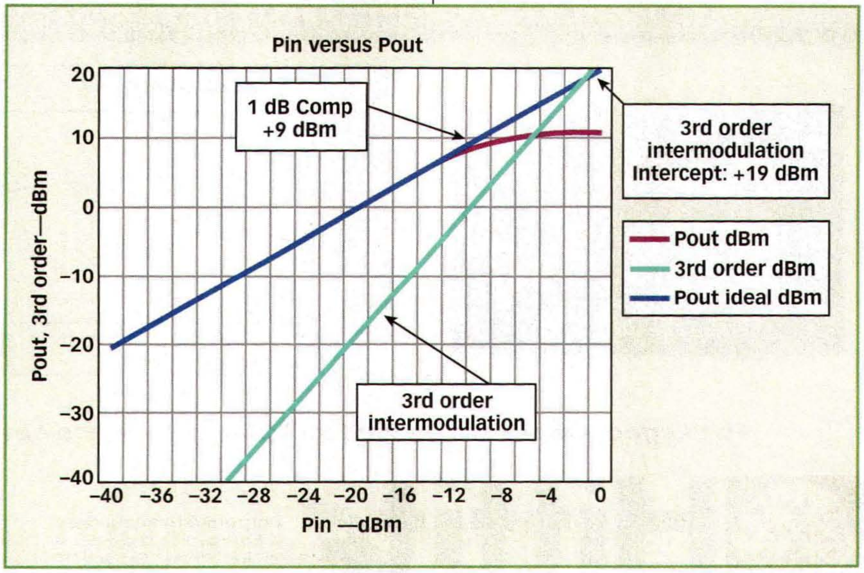
Spurious signals created by the presence of multiple carriers in a given bandwidth are a limiting factor in determining a signal channel's dynamic range. These spurious outputs due to system nonlinearities are the result of mixing of fundamental and harmonics of each of the signals (i.e., intermodulation interference). The easiest form of intermodulation interference to measure is two-tone, third-order intermodulation. This only requires the presence of two carriers at equal power levels closely spaced in frequency. The results of this measurement is used to determine the third-order intermodulation intercept point, a theoretical level used to calculate third-order intermodulation levels at any total power level significantly lower than the intercept point. When more than two signals are present in a single communications channel, the dominant interference is due to carrier-triple-beat (CTB) interference, which is the mixing of the fundamental of three carriers producing an interference signal in the same frequency band as the desired carriers. What fol-

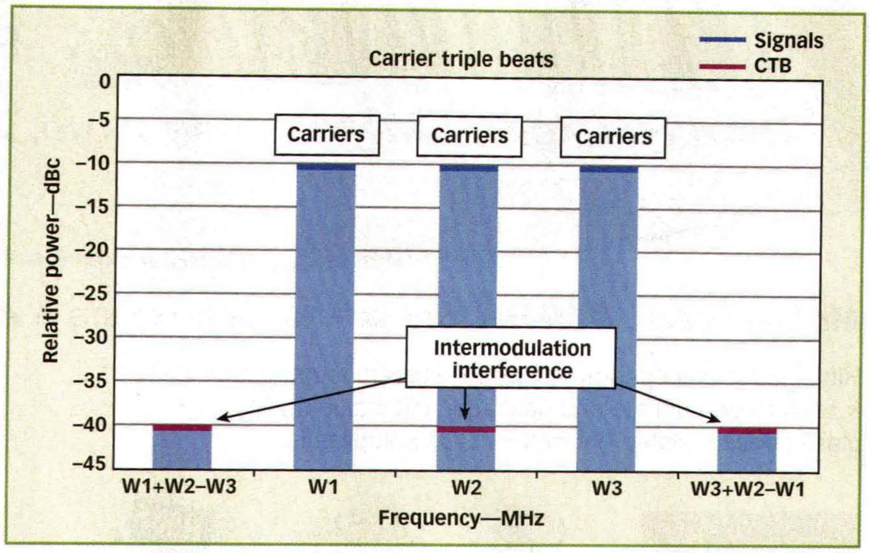


1. This plot of input power versus output power shows the imaginary third-order intercept point.

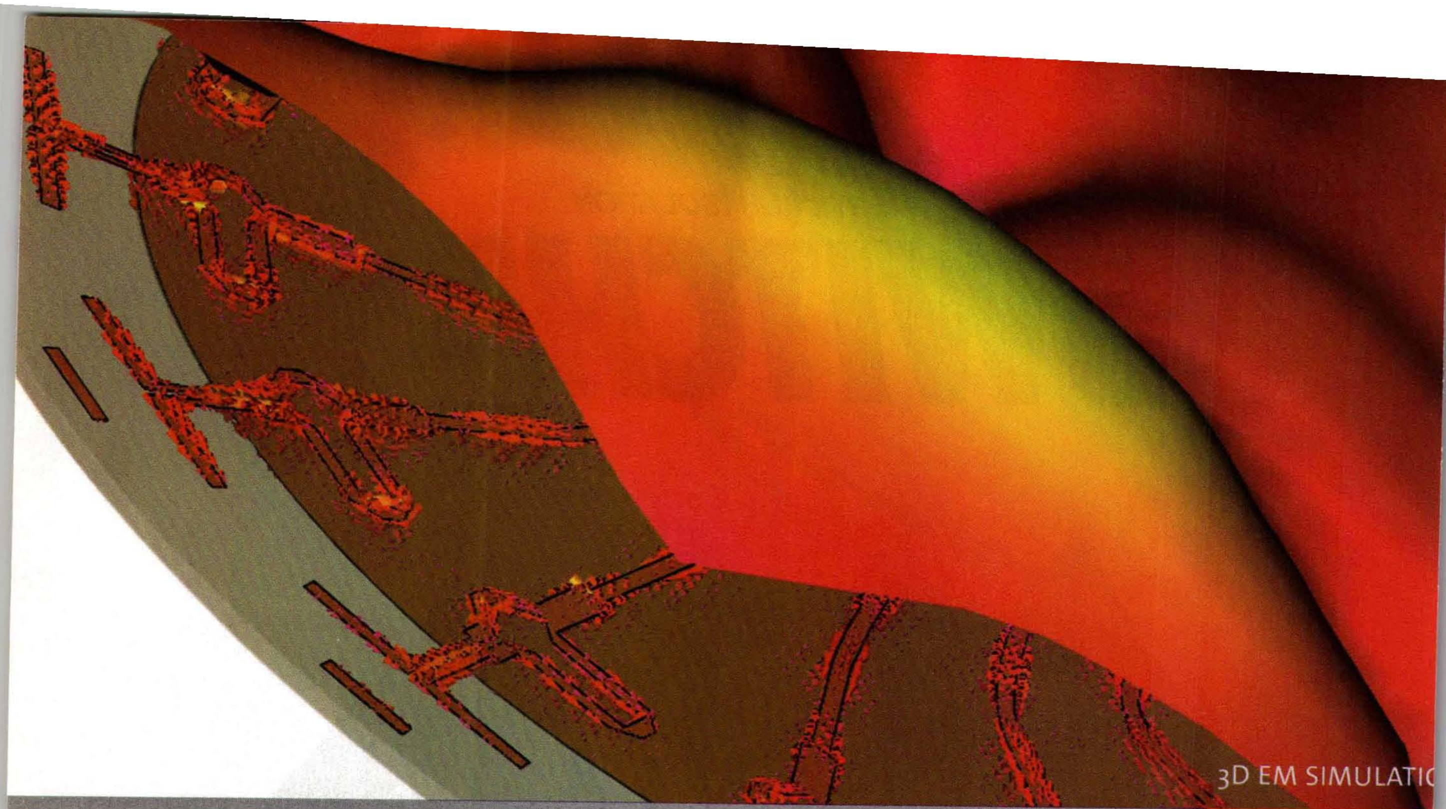
lows is a review of the types of interference generated by multiple carriers and how to estimate their levels.

Third-Order Intercept Point

The third-order intercept point **(Fig. 1)** can be used to calculate carrier triple-beat interference for N carriers. In the limit as the number N gets large, multiple carriers exhibit a noise-like characteristic and can be described as the noise spectral density in a given resolution bandwidth. This suggests a practical alternative to measuring channel interference when a large number of carriers are active. Instead of loading the channel with signal sources, the communication channel is loaded with Gaussian noise covering the entire effective bandwidth. The interference is measured by placing a stopband filter in a similar resolution bandwidth and noting the resulting noise level in the stopband with respect to the noise in the passband. The factor is called the noise power ratio (NPR), a measure of communication-channel performance developed many years ago by the telephone companies and being resurrected today by satellite-communications systems to test the viability of multiple-carrier



2. Carrier-triple-beat (CTB) distortion results when the mixing products of three carriers fall in the same band as the carriers.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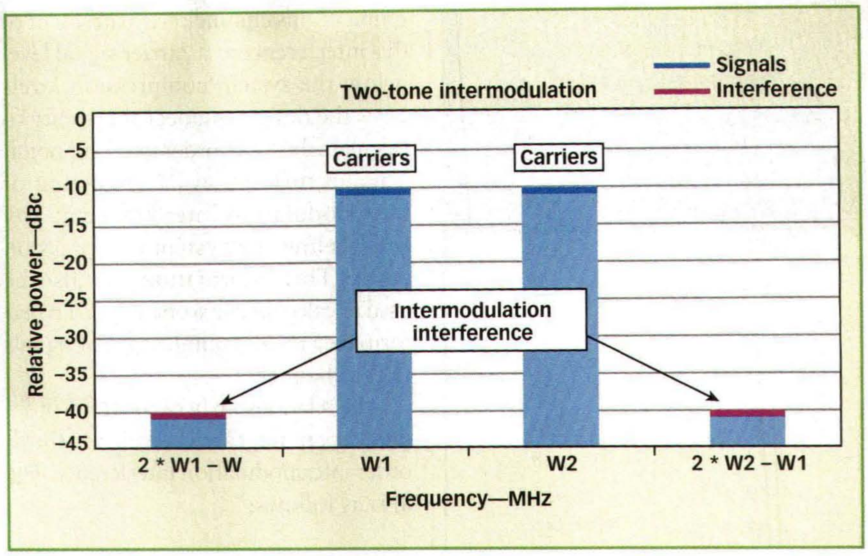
transmissions through a common satellite transponder.

If the total output power is kept constant, the relationship between the two-tone third-order intermodulation interference and the CTB interference for N signals is predictable. Since the results of NPR tests are similar to that of a system with a large number of carriers, these results can be extended to predict the NPR performance of a given system.

The following analysis assumes that all interference is caused by third-order intermodulation, which is usually dominant with higher-order intermodulation having secondary and tertiary effects. Therefore, the results presented are in general a good first-order approximation and should only be used as a convenient tool rather than a exact analytical result.

For system bandwidths less than an octave, even-order intermodulation products are out of band. Odd-order intermodulation products fall in-band, with sidebands close to the carrier. The level of interference is related to the system nonlinearity which can be defined by the theoretical intercept points for each higher-order nonlinearity (e.g., third-order intermodulation is defined by a third-



3. Two-tone intermodulation distortion stems from the mixing of two signals to produce out-of-band interference.

Table 1: Plotting interference versus power level below I_{3rd}

POWER LEVEL BELOW I3rd (I3rd – Ptot) dB	dBc3rd INTERFERENCE LEVEL dBc
5	–16
6	–18
7	–20
8	–22
9	–24
10	–26
11	–28
12	–30
13	–32
14	–34
15	–36
16	–38
17	–40
18	–42
19	–44
20	–46

order intercept point, fifth-order nonlinearity is defined by a fifth-order intercept point, etc.).

For simple (nonlinearized) systems, the third-order nonlinearity is usually the most prominent. In-band third-order distortion is the mixing of a fundamental of one signal and the second harmonic of another signal. The presence of more than two carriers in a nonlinear channel creates a spurious response, consisting of the mixing of three fundamental carriers, i.e., CTB. These spurious CTB signals fall in-band at a level 6 dB higher than two-tone, intermodulation products because there are no second harmonics involved in the production of the interference signal. The level of CTB interference is further enhanced by multiple CTB signals occurring in the same frequency band. **Figure 2** shows three fundamental signals and the resultant carrier triple beats. The interference signals each down –30 dBc, are products of the three carriers at frequencies, W1, W2, and W3.

Third-order intermodulation interference is caused when two signals are present in the same non-linear communications channel. Measurement of this interference at a carrier signal level below the system compression levels gives the design engineer the ability to calculate the third-order intercept point. This, in turn, allows a prediction of intermodulation interference at any level below the system compression levels. This information can also be used to calculate the worst-case CTB performance for any number (N) of signals in the channel.

The relationship between third-order intercept point, carrier level, and third-order intermodulation interference (**Fig. 3)** is as follows:

$$dBc3rd = -2(I_{3rd} - Carrier)$$

where:

dBc3rd = the third-order intermodulation level with respect to a single carrier (dBc),

Carrier = the single carrier output level (dBm), and

I_{3rd} = the third-order intercept point (dBm).

The total output power, P_{tot} (in dBm), assuming both carriers have equal levels, can be written as:

$$P_{tot} = Carrier + 10\log(2) = Carrier + 3\text{ dB}$$

Conversely, the individual carrier power is:

$$Carrier = P_{tot} - 3\text{ dB}$$

Solving for the third-order intermodulation interference (dBc3rd) in terms of total output power yields:

$$dBc3rd = -2(I_{3rd} - P_{tot} + 3\text{ dB})$$
$$= -2(I_{3rd} - P_{tot}) - 6\text{ dB}$$

The third-order intercept point in terms of total power and third-order intermodulation is:

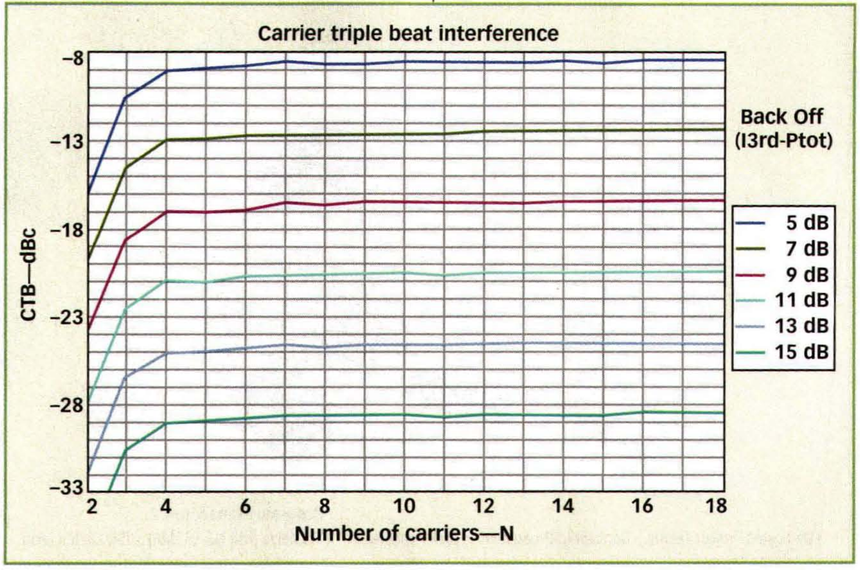
$$I_{3rd} = P_{tot} - 3\text{ dB} - (dBc3rd/2)$$

For convenience, **Table 1** offers interference level (dBc) versus total power below the third-order Intercept point for two tones.

The carrier-triple-beat (CTB) interference level for three carriers (CTB_3) is similar to two-tone intermodulation except that a factor of 6 dB is added to account for the fact that no second-harmonic content is needed to create the in-band interference:

$$CTB_3 = -2(I_{3rd} - Carrier) + 6\text{ dB}$$

Unlike two-tone intermodulation, CTB signals can overlap (Fig. 2), adding noncoherently. When more than three carriers are present in a single channel,



4. These curves show CTB interference for N carriers as a function of total back-off.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the total interference is related to the number of carriers and the spectral position of the carrier. Carriers in the center of the band exhibit the worst-case interference levels, i.e., the highest number of beat frequencies in a given bandwidth (channel). The number of interference carriers (Beats) in any channel for equally spaced carriers is as follows:

$$Beats = N^2/4 + [(N - M))(M - 1)]/2$$

where:

N = the number of carriers, and

M = the carrier position in the channel, $1 \leq M \leq N$ (typically M = 1 is the lowest frequency carrier).

The maximum interference occurs in the center of the band ($M \approx N/2$) where there is the maximum number of beat signals. For N >> 1 the beats ($Beat_{max}$) in the center of the band is:

$$Beat_{max} = 3N^2/8$$

where:

$Beat_{max}$ = the number of noncoherent interference carriers in the same channel.

The total CTB level is determined by calculating the level of each CTB and adding non-coherently the number of beat signals that will fall into the respective band:

$$CTB = -2(I_{3rd} - Carrier\ ) + 6\ dB + 10\log(Beats)$$

The 6 dB is added because the intermodulation is due to the mixing of three fundamental carriers (there are no second harmonics present in the mixing process), and Beats is given as:

$$Beats = N^2/4 + [(N - M)(M - 1)]/2$$

and the total CTB interference is given as:

$$CTB = -2(I_{3rd} - Carrier) + 6 + 10\log\{(N^2/4) + [(N - M)(M - 1)]/2\}$$

The worst-case interference occurs in the center of the band (M = N/2). The total power, assuming all of the carriers have equal power, can be written as:

$$P_{tot} = Carrier + 10\log(N)$$

where:

P_{tot} = the total output power for N carriers are of equal amplitude (dBm).

Solving for the individual carrier power yields:

$$Carrier = P_{tot} - 10\log(N)$$

Substituting total output power for single carrier power and solving for the total CTB gives the following results:

$$CTB = -2[I_{3rd} - \{Ptot - 10\log(N)\}] + 6 + 10\log\{N^2/4 + [(N - M)(M - 1)]/2\}$$

and

$$CTB = -2[I_{3rd} - Ptot] - 20\log(N) + 6 + 20\log\{N^2/4 + [(N - M)(M - 1)]/2\}.$$

Worst-case CTB interference ($M \approx N/2$) is plotted in **Table 2** and shown in **Fig. 4** as a function of total power back-off from the third-order intercept point for various numbers of carriers (N). It is obvious that the CTB interference increases 2 dB for every 1-dB increase in power. For N >> 1 the maximum

Table 2: Plotting worst-case CTB interference

NO. OF CARRIERS N	BACK OFF (I3rd-Ptot) 5 dB CTB dBc	BACK OFF (I3rd-Ptot) 6 dB CTB dBc	BACK OFF (I3rd-Ptot) 7 dB CTB dBc	BACK OFF (I3rd-Ptot) 8 dB CTB dBc	BACK OFF (I3rd-Ptot) 9 dB CTB dBc	BACK OFF (I3rd-Ptot) 10 dB CTB dBc	BACK OFF (I3rd-Ptot) 11 dB CTB dBc	BACK OFF (I3rd-Ptot) 12 dB CTB dBc	BACK OFF (I3rd-Ptot) 13 dB CTB dBc	BACK OFF (I3rd-Ptot) 14 dB CTB dBc	BACK OFF (I3rd-Ptot) 15 dB CTB dBc
2	−16	−18	−20	−22	−24	−26	−28	−30	−32	−34	−36
3	−10.5	−12.5	−14.5	−16.5	−18.5	−20.5	−22.5	−24.5	−26.5	−28.5	−30.5
4	−9.1	−11.1	−13.1	−15.1	−17.1	−19.1	−21.1	−23.1	−25.1	−27.1	−29.1
5	−8.9	−10.9	−12.9	−14.9	−16.9	−18.9	−20.9	−22.9	−24.9	−26.9	−28.9
6	−8.8	−10.8	−12.8	−14.8	−16.8	−18.8	−20.8	−22.8	−24.8	−26.8	−28.8
7	−8.6	−10.6	−12.6	−14.6	−16.6	−18.6	−20.6	−22.6	−24.6	−26.6	−28.6
8	−8.6	−10.6	−12.6	−14.6	−16.6	−18.6	−20.6	−22.6	−24.6	−26.6	−28.6
9	−8.6	−10.6	−12.6	−14.6	−16.6	−18.6	−20.6	−22.6	−24.6	−26.6	−28.6
10	−8.6	−10.6	−12.6	−14.6	−16.6	−18.6	−20.6	−22.6	−24.6	−26.6	−28.6
11	−8.6	−10.6	−12.6	−14.6	−16.6	−18.6	−20.6	−22.6	−24.6	−26.6	−28.6
12	−8.5	−10.5	−12.5	−14.5	−16.5	−18.5	−20.5	−22.5	−24.5	−26.5	−28.5
13	−8.5	−10.5	−12.5	−14.5	−16.5	−18.5	−20.5	−22.5	−24.5	−26.5	−28.5
14	−8.5	−10.5	−12.5	−14.5	−16.5	−18.5	−20.5	−22.5	−24.5	−26.5	−28.5
15	−8.5	−10.5	−12.5	−14.5	−16.5	−18.5	−20.5	−22.5	−24.5	−26.5	−28.5
16	−8.4	−10.4	−12.4	−14.4	−16.4	−18.4	−20.4	−22.4	−24.4	−26.4	−28.4
17	−8.4	−10.4	−12.4	−14.4	−16.4	−18.4	−20.4	−22.4	−24.4	−26.4	−28.4
18	−8.4	−10.4	−12.4	−14.4	−16.4	−18.4	−20.4	−22.4	−24.4	−26.4	−28.4


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interference in the center of the band with all carriers of equal amplitude can be solved:

$$CTB = -2(I_{3rd} - P_{tot}) - 20\log(N) + 6 + 10\log(3N^2/8)$$

Factoring out the N^2 term,

$$CTB = -2(I_{3rd} - P_{tot}) - 20\log(N) + 6 + 10\log(3/8) + 10\log(N^2)$$
$$CTB = -2(I_{3rd} - P_{tot}) - 20\log(N) + 6 + 10\log(3/8) + 20\log(N)$$

The 20logN terms cancel, leaving a simplified equation for CTB (in dBc):

$$CTB = -2(I_{3rd} - P_{tot}) + 6 + 10\log(3/8)$$

Evaluating 10log(3/8) results in the following equation, relating CTB interference, third-order intercept point, and total output power for interference in the center of the band and the number of carriers much greater than one (N >> 1):

$$CTB = -2(I_{3rd} - P_{tot}) + 1.74\ dB$$

The equations for two-tone intermodulation interference and CTB interference are related and a minor amount of manipulation results in a direct relationship between the expected respective interference for equal total output powers. This is significant because a relatively simple measurement (two-tone, third-order intermodulation) can be used to predict performance for a more complex multiple carrier system. These results although valid are only approximations of the actual performance. In deriving this relationship, the channel passband is assumed ideal and higher-order intermodulation effects must be ignored.

The equation for two-tone (N = 2) third-order intermodulation interference was given previously as:

$$dBc3rd = -2(I_{3rd} - P_{tot}) - 6\ dB$$

Rearranging the equation results in:

$$dBc3rd + 6\ dB = -2(I_{3rd} - P_{tot})$$

Using the CTB equation (for multiple tones, with N >> 1)

$$CTB = (-2)(I_{3rd} - P_{tot}) + 1.74\ dB$$

and substituting (dBc_{3rd} + 6 dB) from the two-carrier equation for $-2(I_{3rd} - P_{tot})$ in the CTB equation results in:

$$CTB = dBc3rd + 6\ dB + 1.74\ dB$$

Combining terms yields:

$$CTB = dBc3rd + 7.7\ dB$$

Third-order intermodulation interference is caused when two signals are present in the same non-linear communications channel.

which directly relates the results of the two-tone intermodulation test results with the expected results for N carriers and is valid under the following conditions:
1. The total output power is the same in both measurements.
2. The number of carriers is N >> 1.
3. Higher-order effects are not significant.
4. The channel characteristics are the same for all frequencies of interest.
5. The level of each carrier is equal.

As N gets large and approaches infinity, the individual carriers behave as a noise spectral density function and the CTB interference exhibits the first approximation of the results obtained from a NPR test. Extrapolating from this, a first-order approximation of NPR can be obtained from two-tone, third-order intermodulation data, whereas the NPR is approximately 7.7 dB above the result obtained from a two-tone, third-order intermodulation test. A word of caution must be inserted to prevent this equation from becoming any more than a rough approximation. The two-tone, third-order intermodulation measurement is made in a relatively small frequency band while the NPR can apply over a considerably larger bandwidth with variable band characteristics making this approximation even less accurate than expected.

5. The author has served as an Adjunct Professor at Hofstra University and has designed microwave components and systems for satellite communications throughout his career.

When the total output power is equal, the interference level with respect to the carrier for multiple signals N, where N >> 1, is 7.7 dB greater than the interference level found for two-tone, third-order intermodulation **(Fig. 5)**. Although this is a convenient closed form, in actual practice this is only a first-order approximation of the expected results. Not considered, but usually not necessary for a first-order approximation, are the effects of higher-order intermodulation, nonideal signal-channel characteristics, and the effects of signal modulation (the current analysis was based on CW signals). MRF

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Global Positioning System (GPS) receivers are poised to play a critical role in wireless communications as a result of the United States Federal Communications Commission's (FCC's) E911 directive and location based services (LBS) expected to follow on the heels of the mandate. Successful E911/LBS products and services will require solutions with features that can implement GPS in mobile telephones, for low cost, with low power consumption high accuracy, high sensitivity, and good noise immunity.[1]

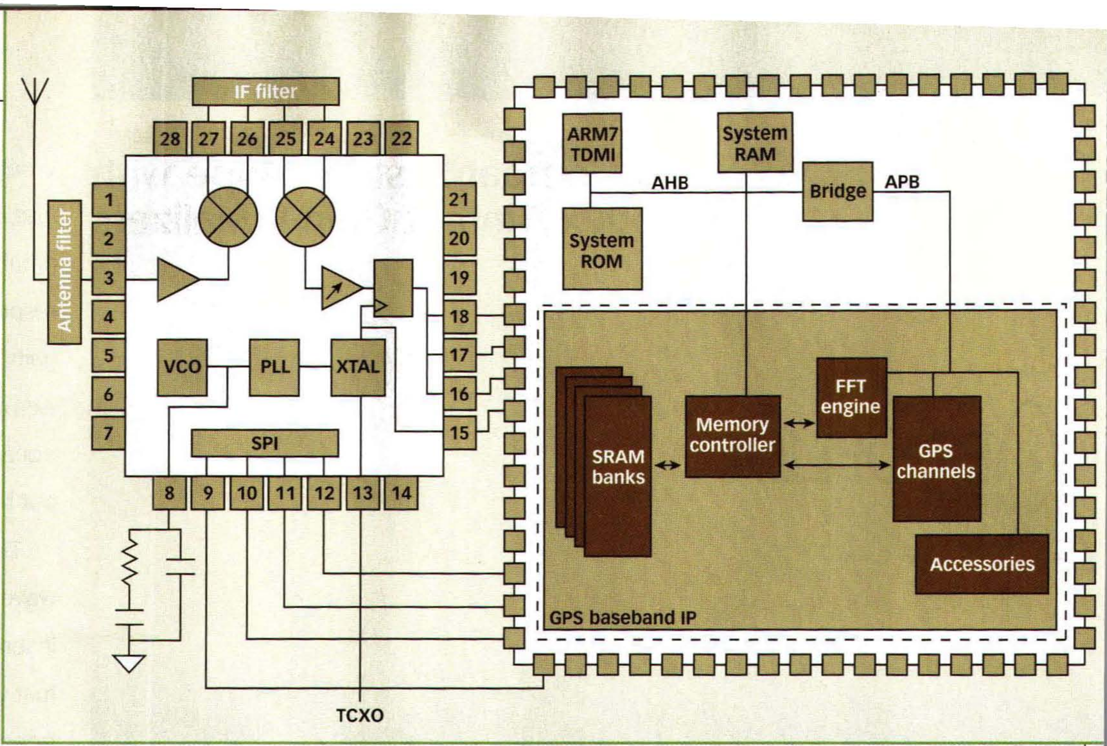
A GPS receiver typically comprises two functions: the radio front end and the baseband digital signal processor (DSP). Complementary-metal-oxide-semiconductor (CMOS) digital technology improvements now allow baseband designs to be ported across silicon vendors and be realized at the system level using reliable processors such as the DSP cores from CEVA (Northampton, England). Ideally, the RF front end would also be available in a standard process and portable across a variety of suppliers.

Support of embedded GPS solutions involves the development of an approach to provide appropriately featured silicon GPS on RF integrated circuit (RF IC) solutions with minimal redesign time. What follows is an explanation of that approach and how software modeling methods were used to evaluate RF IC design compromises, based on the Advanced Design System (ADS) simulator from Agilent Technologies (Santa Rosa, CA).

Radio-receiver design normally breaks down into two aspects: the top or system-level requirements, such as chip gain and frequency planning, and the individual circuit block performance. Traditional design approaches use separate tools for system, DSP, and RF design. RF IC designers typically must reconcile different modelling results of analog, digital, and RF signals in high-density circuits. For example, integrating bipolar transistors alongside passive components and high-speed CMOS logic introduces significant uncertainty in the operational behavior of the circuits, illustrated

Table 1: GPS jamming frequencies in a cellular handset

CELLULAR STANDARD	TRANSMIT FREQUENCY	MAXIMUM HANDSET OUTPUT POWER
GSM	880 to 915 MHz 1710 to 1785 MHz	+33 dBm
IS-95	824 to 849 MHz	+23 dBm
PCS	1850 to 1910 MHz	+24 dBm

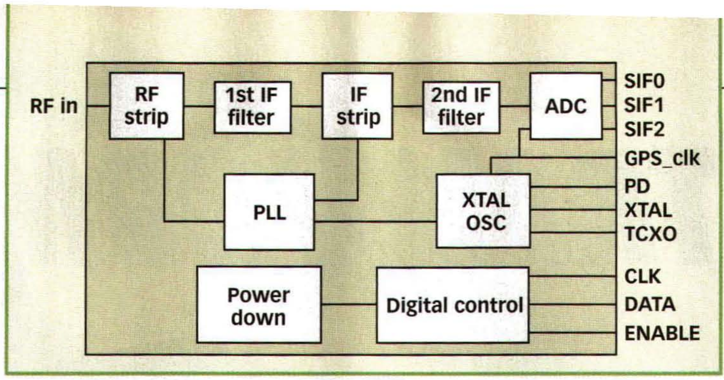


1. This block diagram shows the functional blocks of the GPS receiver and baseband processor.

by the need to model a phase-locked loop (PLL), where the designer is faced with having to co-simulate digital counters/dividers with the analog voltage-controlled oscillator (VCO).

The initial design and development of a GPS radio requires a careful design process focused on the particular and specific attributes of the target process technology. Converting this into intellectual property (IP) for porting to other processes requires an approach that will reduce the development time and cost significantly below that of the original design phase. Indeed, most customers have very short development times that can be typically 50 to 70 percent of the time taken for the first demonstrator design.

As a result, a methodology was needed that would support frequency-domain and mixed-domain simulation technologies; optimization and statistical design tools; and additional device, system, and behavioral models. This method-



2. This block diagram shows the RF section of the XPERT-GPS platform, a design that can be modified for a wide range of embedded mobile applications.

ology would allow both a top down and bottom up approach so that transistor level changes due to the different process models can be transported to the system level. ADS allows the use of both time-domain and harmonic-balance nonlinear simulation techniques.

This approach made it possible to compare the trade-offs of a single-chip GPS receiver on an advanced 0.13-μm CMOS process and a design developed with separate RF and digital chips (allowing the digital IP to be incorporated into a host chip). The software helped determine that overall system performance would benefit from a separate radio on an advanced silicon-germanium (SiGe) BiCMOS process **(Fig. 1)** The radio design is the XPERT-GPS RF platform **(Fig. 2)** which provides the radio front end for a GPS developed for use in mobile communications, such as handsets and personal digital assistants (PDAs).

The radio design uses a SiGe bipolar CMOS (SiGe BiCMOS) process to achieve a high level of integration, a noise figure of less than 1.5 dB, low power consumption, and low system implementation cost. The radio downconverts the GPS L1 band at 1575.42 MHz and performs a selectable 1-b sign/magnitude or 2-b-sign/1-b magnitude analog-to-digital (ADC) conversion to produce a baseband signal at 3.78 MHz, which feeds the baseband processor.

A variable frequency plan provides the necessary local oscillator (LO) and baseband clock frequencies using an external temperature-compensated crystal oscillator (TCXO), enabling the use of a single board design for different reference clocks from 10 to 26 MHz. Alternatively, a single crystal may be connected to the device using the built-in oscillator circuitry for applications requiring a lower-cost solution.

Key challenges on the RF subsystem are to achieve the GPS requirements of image rejection simultaneously with the capability for co-operational functionality within a mobile-telephone handset. Coprocessing functionality must address both the hostile RF environment and the need to optimize the scarce resources of space, bandwidth, DC power, processing power, or millions of instruc-

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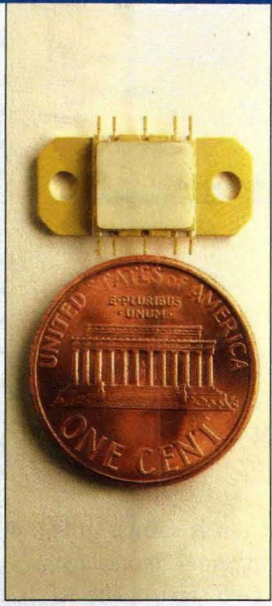

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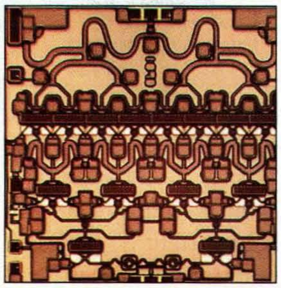

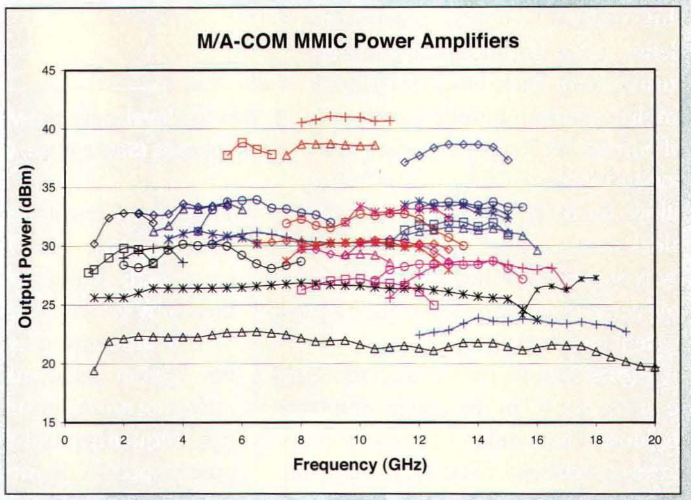

Part Number	Frequency (gHz)	Bias (V)	PSAT (dBm)	Gain (dB)	Current (mA)
HIGH POWER AMPLIFIERS					
MAAPGM0035-DIE	2.5 - 5.5	8 / -2	32	17	850
MAAPGM0021-DIE	4.5 - 9	8 / -2	33	17	750
MAAPGM0025-DIE	5.5 - 7	8 / -2	38	17.5	2500
MAAPGM0024-DIE	7.5 - 10.5	8 / -2	38	26	2500
MA08509D	8 - 11	10 / -2	40	22	4500
MAAPGM0019-DIE	9.5 - 13	8 / -2	32	19	1200
MAAPGM0016-DIE	11.5 - 15	8 / -2	37	16	3000
MAAPGM0018-DIE	12 - 15.5	8 / -2	33	18	1200
MAAPGM0043-DIE	13.5 - 15	88 / -2	32	17	1000
MAAPGM0045-DIE	11.5 - 15	8 / -1.8	33	19	1000
MEDIUM POWER AMPLIFIERS					
MAAPGM0026-DIE	0.8 - 3.3	8 / -2	28	20	300
MAAPGM0036-DIE	1.2 - 3.2	8 / -2	31	20	700
MAAPGM0027-DIE	2 - 4	8 / -2	30	22	350
MAAPGM0028-DIE	2 - 8	8 / -2	28	14	450
MAAPGM0052-DIE	4 - 19	8 / -5	26	13	500
MAAPGM0022-DIE	3 - 6	8 / -2	31	17	900
MAAPGM0029-DIE	3.5 - 6.5	8 / -2	31	20	400
MAAPGM0030-DIE	5 - 9	8 / -2	30	17	400
MAAPGM0056-DIE	6.5 - 14	8 / -5	31	25	800
MAAPGM0051-DIE	7.5 - 13	10 / -2	31	15	400
MAAPGM0038-DIE	7.5 - 13.5	8 / -2	31	19	1100
MAAPGM0034-DIE	8.0 - 12.5	10 / -2	28	15	200
MAAPGM0039-DIE	8.0 - 13.0	8 / -2	29	15	600
MAAPGM0033-DIE	9.5 - 11.0	10 / -2	30	14	400
MAAPGM0040-DIE	10.5 - 15.5	8 / -2	27	20	250
MAAPGM0041-DIE	11.0 - 15.0	8 / -2	31	20	600
MAAPGM0042-DIE	11.5 - 16.0	8 / -2	31	20	600
MAAPGM0044-DIE	11.5 - 17.0	8 / -2	27	20	300
MAAPGM0005-DIE	12.0 - 19.0	7	23	15	200
MAAPGM0047-DIE	16.0 - 19.5	8 / -2	26	15	350
MAAPGM0046-DIE	15.5 - 18.0	8 / -1.8	26	15	350
MAAPGM0049-DIE	24.5 - 29	6 / -1.6	27	13	600
MAAPGM0012-DIE	31.5 - 36.0	5 / -1.2	17	16	200
MAAPGM0013-DIE	32.0 - 36.0	6 / -1.2	23	13	700
MAAMGM0002-DIE	1 - 18	5 / -5	21	9	100
MAAMGM0003-DIE	1 - 15	5 / -5 variable	26	7.5 (max)	480 (max)
MAAMGM0007-DIE	2.0 - 18	5	23	9	200

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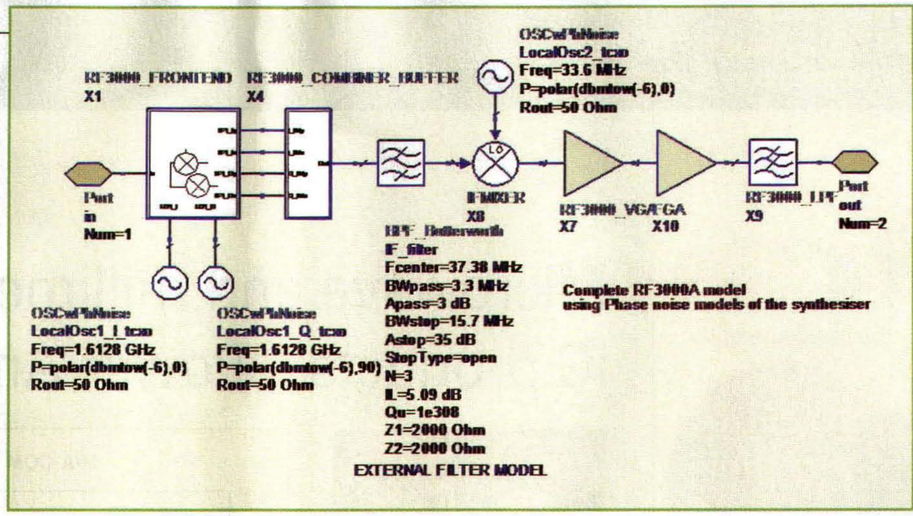
tions per second (MIPS in terms of clock cycles) in the presence of interferers generated by the mobile-telephone protocols.

GPS RF models were developed at multiple abstraction levels using ADS to generate and send GPS signals through to a single-channel baseband correlator for demodulation. With this approach, it was possible to define, optimize, and specify the performance of each block for silicon implementation, simplifying the task of porting the design to another semiconductor process. The approach also allows the RF IC IP to be used as a CEVA block in a customer's test bench, thereby reducing the time taken to simulate and derive probable performance in a given system environment.

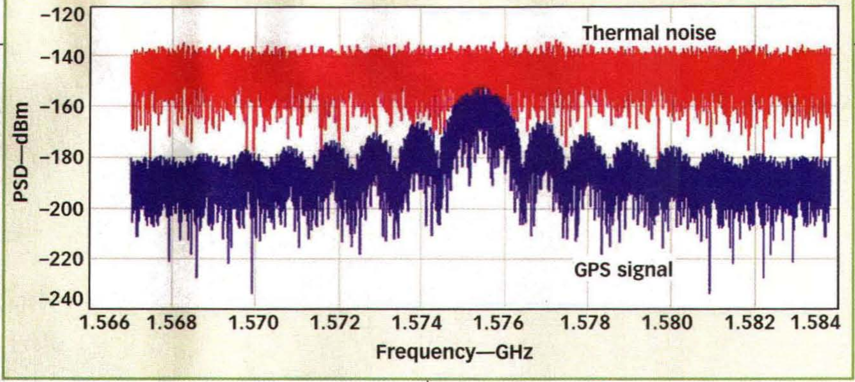


3. This top-level view shows the GPS RF IC designed with the ADS software from Agilent Technologies (Santa Rosa, CA).

Figure 3 shows the top-level schematic of the RF IC in the design simulator window. The simulator allows the properties of each block to be displayed so that simulation environment parameters can be easily observed. This is important since each symbol may contain sub-hierarchy information.

The simulator must be able to model key system performance parameters, including noise, linearity, gain, sensitivity, frequency, and modulation. The power spectral density (PSD) for a typical GPS spectrum is shown in **Fig. 4** along with thermal noise. Note the sinx/x nature of the GPS signal. The RF IC must process a signal that is about 20 dB below the noise level; only by performing integration until the signal-to-noise ratio (SNR) is greater than zero can the receiver recover the GPS signal from the noise.

The simulator's many functions support a large variety of test scenarios. The harmonic-balance simulator, for example is used mainly for evaluating RF block specifications for nonlinear behavior where signals mix or compress in the frequency domain (as in mixer noise analysis). The complete system is then cosimulated using Agilent Ptolemy, an ADS module. Together with the circuit envelope simulator, it allows the front end of the code recovery and correlation digital logic in the baseband to be cosimulated with analog blocks so that effects on data demodulation can be observed. This is an efficient technique where the time step is chosen from the modulation bandwidth rather than the highest frequency of the system. The technique is very efficient when analyzing modulated waveforms since calculations are only done around the frequency of interest. For example, a time-domain analysis with SPICE might use a time step of say 50 ps when simulating a mixer with 1.6-GHz LO and therefore result in long simulation times if the frequency band of interest is three times the frequency of the LO.



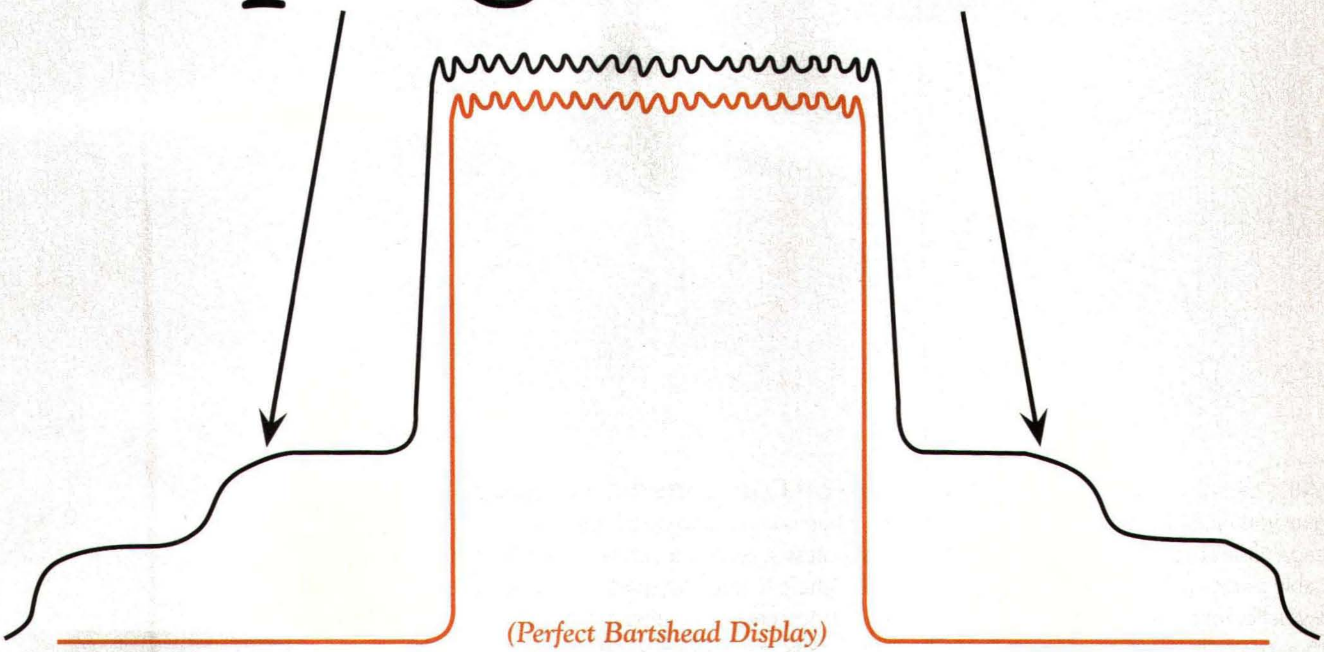
4. This power-spectral-density (PSD) plot shows the level of thermal noise that a GPS receiver must overcome to extract typical GPS signals.

A GPS receiver's capability to operate in the presence of unwanted frequencies is a good indicator of the design's suitability for use as an embedded receiver within a cellular telephone. The telephone's own frequencies can act as potential jammers for the GPS receiver depending on their power levels **(Table 1)**.

Blocking/jamming immunity is a measure of the receiver's capability to capture GPS signals in the presence of interfering signals. This refers to the receiver capability to reject unwanted images that appear within the same frequency spectrum as the desired image, f_{if}. For example, an unwanted image is generated by any spectral components at $f_{rf} + 2f_{if}$ mixing with f_{lo}.

Figure 5 shows the nonlinearity of the GPS RF IC as a function of the jam-

Danger. Sloping Shoulders.



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ming frequency. The receiver remains linear with GPS signal levels of –130 dBm and jammer power levels to about –90 dBm. The incorporation of GPS in a cellular handset means that a jammer will be operating nearby at the cellular frequency, about 1800 MHz in GSM systems.

A high jamming power level can cause the generation of spurious signals if the level exceeds the linear range of the GPS receiver's various circuit blocks. Out-of-band jammers can mix with spectral components to create unwanted mixing products (spurious signals) in the same frequency band as the desired signal, f_{if}. If the power levels are high enough, the resulting spurious products may exceed the linear range of the circuit, resulting in the circuitry's inability to retain GPS signal lock. For the jamming scenario, an output level of +33 dBm was used to simulate the incident jamming power level transmitted by the GSM antenna. A front-end filter model was used in the simulation.

Table 2: XPERT-GPS RF measured performance

PARAMETER	MEASURED VALUE	SIMULATED VALUE
Power gain (Gp)	23 dB	24 dB
Noise figure (NF)	1.9 dB	1.4 dB
IIP3	-31 dBm	-30 dBm
Current required	9.9 mA	10.4 mA *
Image rejection	33 dB	27 dB
Return loss	14 dB	20 dB
1-dB compression point	-41 dBm	-40 dBm

*Excludes synthesiser current

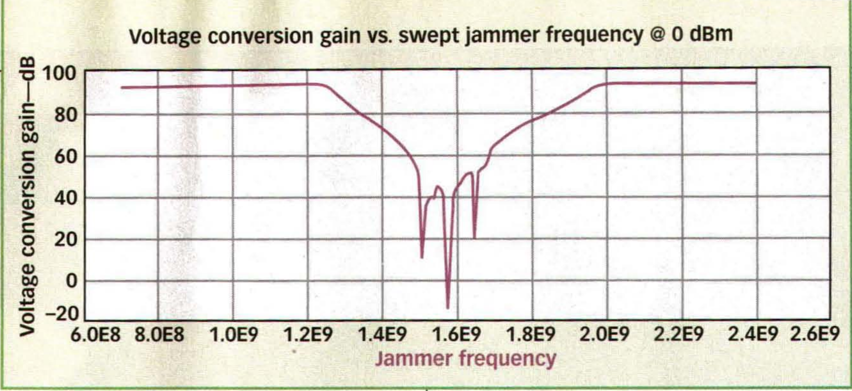
For higher-level GPS system simulations, the Agilent Ptolemy and circuit envelope cosimulation environment allows analysis of demodulated data at baseband. It also allows operators to view the modeled RF IC cosimulation test bench (not shown) that was used to define the system performance in schematic form. The schematic diagrams were used as the basis of harmonic balance and circuit envelope simulation environments. Such test setups even allow parameter sweeps (such as interferer power levels) with the capability of observing the effects on the carrier-to-noise ratio (CNR). Depending upon the circumstances, a CNR of about 40 dB/Hz or more would be expected for good GPS performance.

Figure 6 shows cosimulation results on the RF IC with input thermal noise, phase noise, and receiver noise figure. The estimated CNR in the data demodulator is shown as a function of time; the length of the modulated code is 20 ms. The spectrum also shows the correct shape for a band-limited IF signal.

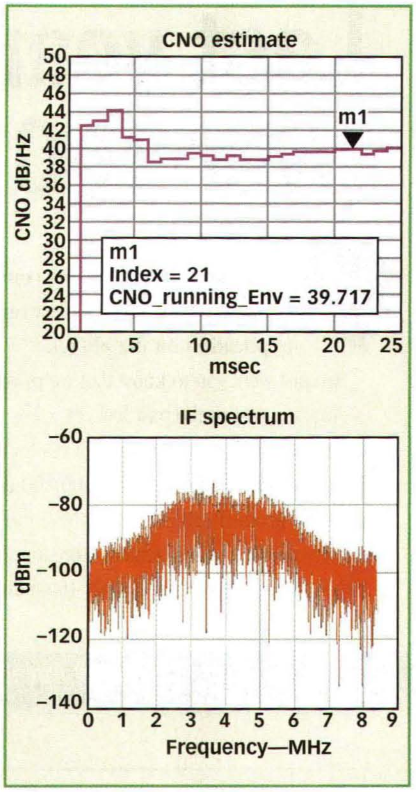
Figure 7 shows an I/Q polar plot of the demodulated GPS signal. In this case, the GPS signal carries no data and, therefore, only one symbol is shown. This is a better way of looking at the quality of the demodulated signal; a poor signal

to noise ratio will result in a greater distribution of the symbols. As noise and phase contributions are removed, the CNR increases and symbol distribution becomes tighter as the SNR improves.

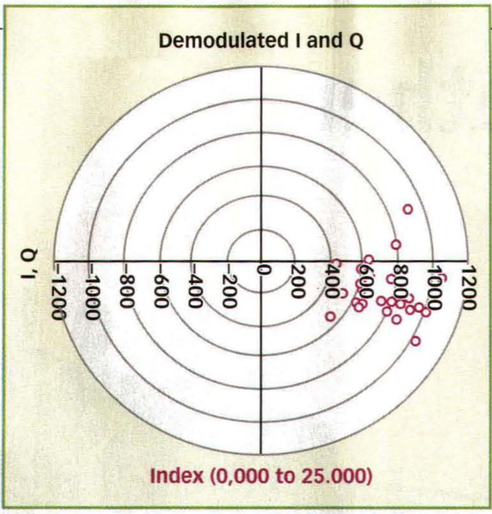
A key consideration in designing a GPS RF IC involves the IF filter: it must provide adequate rejection of out-of-band jamming signals but not occupy too much of the semiconductor die area or consume too much current. **Figure 8** helps evaluate these trade-offs, showing a simulation that evaluates CNR degradation as a function of filter bandwidth and order. It indicates that the CNR has an inverted bathtub response with the bandwidth of the IF filter. Recalling the sinx/x response of the GPS signal, bandwidths narrower than about 1.5 MHz cut-out part of the fundamental as well as the lobes



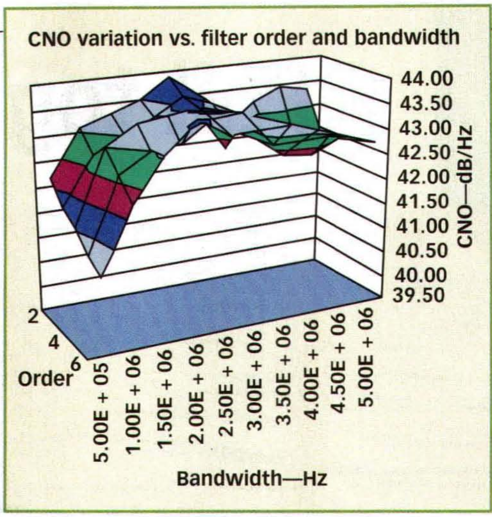
5. To show the nonlinearity of the GPS RF IC design, voltage-conversion gain was simulated as a function of swept jammer frequency.



6. Receiver noise, thermal noise, and phase noise were included in this co-simulation of RF IC receiver performance.



7. This I/Q polar plot shows the simulated performance of the RF IC based on demodulated GPS signals.



8. To optimize the GPS filter for size, rejection, and cost, the receiver CNR was simulated as a function of filter bandwidth and order.

of the sinx/x waveform, effectively reducing the SNR. For bandwidths above approximately 3 MHz, the increase in SNR contained in the sidelobes is outweighed by the increased integrated noise, resulting in degraded CNR. In terms of filter order, there appears to be little gained by using filters of more than four or five order, since there is no further increase in CNR. This type of analysis leads to the use of a filter that provides adequate CNR performance without added complexity and cost.

The ultimate measure of a GPS receiver's performance is the design's capability of tracking GPS satellites. **Figure 9** shows the receiver's early-prompt-late correlation outputs using the XPERT-GPS RF in the NS3000 GPS platform measured over an integration time of 16 ms. The baseband produces early, late, and prompt versions of the code; the resulting correlation triangle provides a visual guide to the quality of the GPS signal through the XPERT-GPS RF. The three distinct steps can clearly been seen.

To verify the simulated results, characterization of the RF and IF sections were carried out separately. The RF strip, consisting of an LNA, a pair of I/Q mixers, and a combiner with drivers, was evaluated as a single block with an input signal at 1.575 GHz and output at the first IF. Key performance parameters are summarized in **Table 2**, with a complete module of the GPS receiver used to obtain some of the system measurements shown in **Fig. 10**.

The authors have found ADS to be a powerful tool in the analysis and design of the XPERT-GPS RF, helping to define and verify the next generation GPS radio at a number of levels, from block-level simulation through system simulations, including code recovery/correlation at baseband. ADS has made it possible to identify and explore the key parameter trade-offs in GPS receiver design.

In addition to a better design process, this development methodology renders design techniques and trade-offs more visible to designers and IP users. Design engineers, product developers, and system integrators are able to verify the suitability of designs and IP for their needs, reducing risks and costs while improving time to market. The chip is commercially available as the MAX2741 from Maxim Integrated Products (Sunnyvale, CA). MRF

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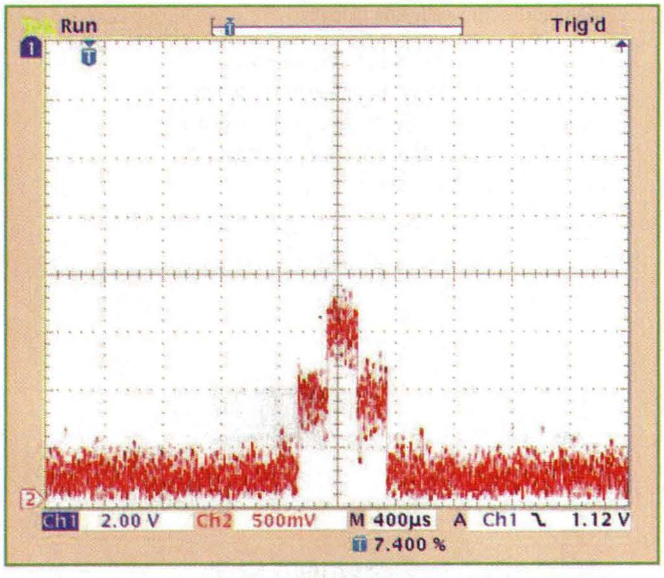
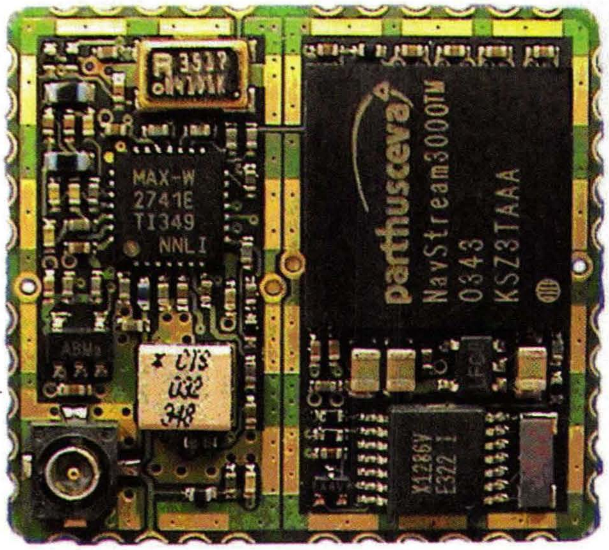
2. Elliott D. Kaplan "Understanding GPS: Principles and Applications."

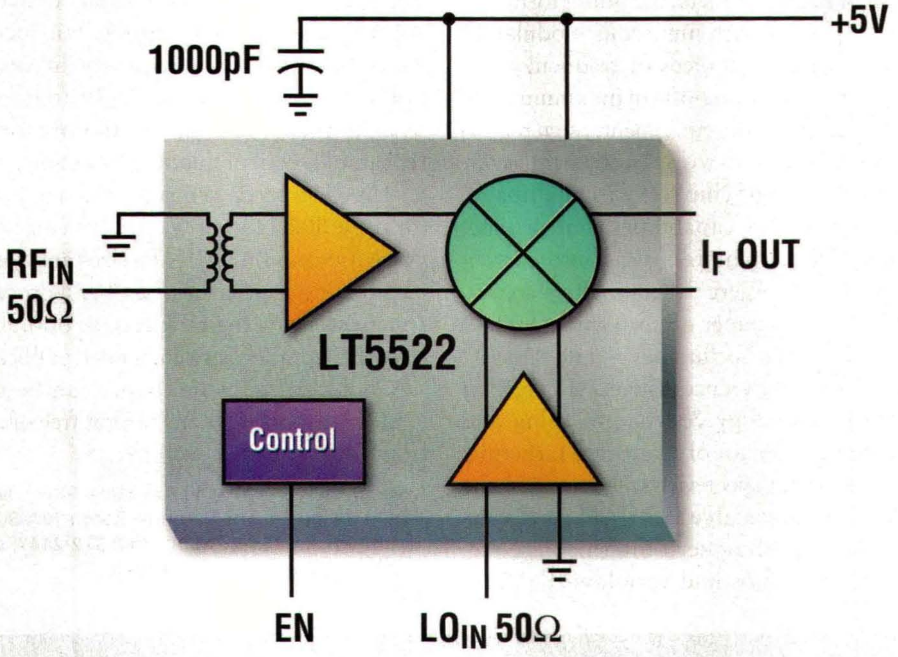


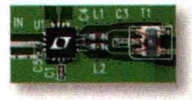
9. This plot shows the simulated early-prompt-late correlation outputs using the XPERT-GPS RF IC design.



10. To verify the accuracy of the simulations, measurements were performed on this GPS receiver module.

High Linearity, Low LO Drive





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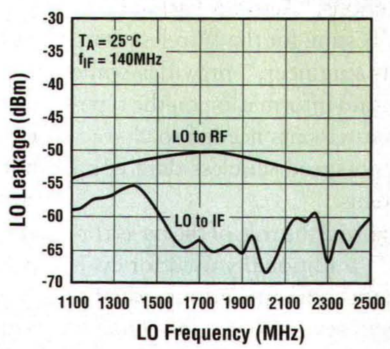
LO Leakage vs LO Frequency



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WIRELESS LOCAL-AREA NETWORKS (WLANs) have become somewhat ubiqitous in large cities, where WLAN "hotspots" offer network access to laptop computer owners with properly equipped WLAN transceiver cards. A variety of network choices are currently available to developers of WLAN products, including format at 2.4 and 5.2 GHz with numerous modulation formats. With the choices of frequency and modulation come trade-offs in maximum data rate and the cost of the equipment, often requiring product developers to use multiple transceiver chip sets or single chip sets with multiband, multimode WLAN capabilities. For product developers seeking more insight into current WLAN choices, Agere Systems offers a comprehensive white paper on the topic, "802.11 Wireless Chip Set Technology White Paper."

Written by Lawrence Rigge, Manager of Wireless Technology & Roadmapping and Tony Grewe, Director of Strategic Marketing, the 12-page white paper reviews the various receiver architectures available to WLAN developers and users, including zero-intermediate-frequency (ZIF) radios and very-low-IF (VLIF) radios. The direct-conversion ZIF radio has advantages of requiring minimal external components due to lower filter requirements, suporting smaller printed-circuit-board (PCB) areas, and reduced power consumption. By quickly converting analog signals to the digital realm, a ZIF chip is less subject to process variations that other WLAN receiver architectures. For increased data rates, orthogonal frequency division multiplexing can be used with VLIF architectures to support data rates of 54 Mb/s or more with repeatable semiconductor processing.

The white paper compares technology options for IEEE 802.11a/b/g WLAN systems in terms of CMOS and BiCMOS die sizes and costs, IC partitioning approaches, baseband processing, system security, digital interface options, and ease of integration into embedded applications.

Copies of the white paper can be downloaded in Adobe PDF file format free of charge from the company's website.

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The white paper compares technology options for IEEE 802.11a/b/g WLAN systems in terms of die sizes and cost, partitioning approaches, and digital interface options.

Finding Solutions For Wireless Data Measurements

EVALUATING WIRELESS-COMMUNICATIONS systems inevitably involves testing high-speed data streams, and engineers are often faced with the use of instruments that are somewhat different than the traditional tools of RF measurements, such as power meters and spectrum analyzers. Fortunately, a six-page application note from Aeroflex Test Solutions, "Aeroflex Fastbit Error Rate Analyzer—Testing for the Wireless Data Communications Engineer," provides some valuable background information on the types of tools and measurements needed to characterize modern high-speed wireless data communications systems.

The note recognized the role of the bit-error-rate tester (BERT) traditionally used for evaluating wireless data communications systems, but also introduces several other instruments that will serve, including protocol analyzers and the company's own solution of choice: the model FB100A Fastbit Error Rate Tester teamed with a model FB2000A Noise Generator and Channel Impairment Simulator. The combination of instruments makes it possible to evaluate bit-error-rate (BER) performance under changing conditions of additive white Gaussian noise (AWGN), multipath, and signal fading.

The note reviews the use of probability distribution functions (PDFs) during the characterization of a wireless data communications systems and how the PDFs can be applied to a BER measurements to obtain a given level of confidence in the measurement results. The note also describes a technique for performing BER parameter calculations when there are not bit errors in the system and provides several equations for analysis. In addition, the literature describes how waterfall curves can be used to evaluate system performance.

Copies of the six-page application note are available for free download from the company's website.

Aeroflex Test Solutions, 35 South Service Rd., Plainview, NY 11803; (800) 835-2352, (316) 522-4981, FAX: (316) 522-1360, e-mail: info-test@aeroflex.com, Internet: www.aeroflex.com.

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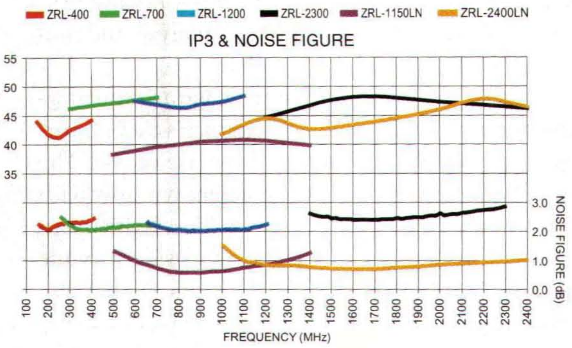

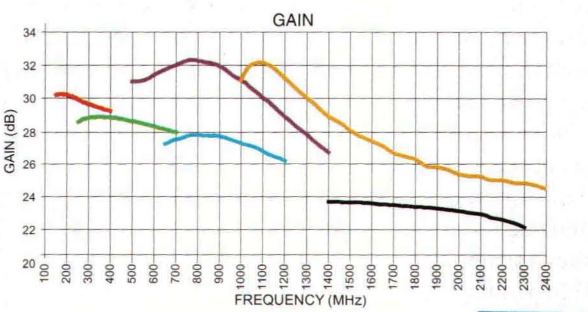

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ZRL-1200	650-1200	27	2.0	46	24.3	119.95
ZRL-2300	1400-2300	24	2.5	46	24.6	119.95
ZRL-2400LN	1000-2400	27	1.0	45	24.0	139.95

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cover story

Smart Signal Analyzer Decodes 100 Hz To 8 GHz

An innovative front-end architecture based on a 9.5-to-17.5-GHz LO arms the Signature analyzer to capture modulation bandwidths to 30 MHz with stunning frequency and amplitude accuracy.

JACK BROWNE
Publisher/Editor

Signal analysis in this "wireless age" requires a fair amount of processing power. In the new model MS2781A Signature™ High Performance Signal Analyzer from Anritsu Co. (Morgan Hill, CA), it is safe to say that the power is linked to both hardware and software. Not only does the instrument's advanced front-end architecture allow it to sweep a 30-MHz-wide swath across a total bandwidth of 100 MHz to 8 GHz, but also its built-in Windows XP Professional oper-ating system and touch-screen display make it simple to program and provide the flexibility to link seamlessly with industry-standard analysis and simulation software tools.

In spite of the fact that this is a complex instrument with frequency-domain and time-domain measurement capabilities, Signature's clean front-panel display **(Fig. 1)** offers an immediate indication of its ease of use. The large (10.5-in.) touch-screen display frames the measurement window with the familiar Windows XP Professional operating system toolbars (with drop-down menu items). Large function keys on the right-hand side provide access to frequency, amplitude, bandwidth, and marker functions; these keys are backlit when activated to alert an operator. Additional function keys offer instant access to trace adjustments, display options, sweep controls, triggers, system commands, file management, and help files. Of course, all of these controls and adjustments can also be accessed by means of the Windows XP Professional drop-down menus.

All of this control would be meaningless without a powerful hardware engine, and Signature brings a platform that combines aspects of a microwave spectrum analyzer and a vector signal analyzer. The hardware is based on fundamental mixing of input signals using four stages of downconversion **(Fig. 2)**. The first stage features a synthesized local-oscillator (LO) tuning from 9.5 to 17.5 GHz and yielding a fixed intermediate frequency (IF) of 9.5 GHz. This IF is then mixed with an 8.4-GHz second LO to produce a second IF of 1.1 GHz. This second IF is in turn mixed with a 1-GHz third LO to yield a third IF of 75 GHz, which is then mixed with a fourth LO of 85.7

1. The Anritsu Signature™ High-Performance Signal Analyzer can capture and demodulate signals as wide as 30 MHz over a total range of 100 Hz to 8 GHz.

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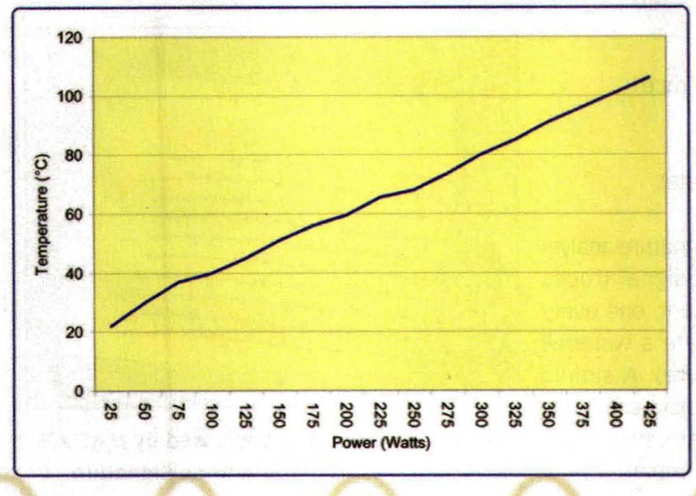

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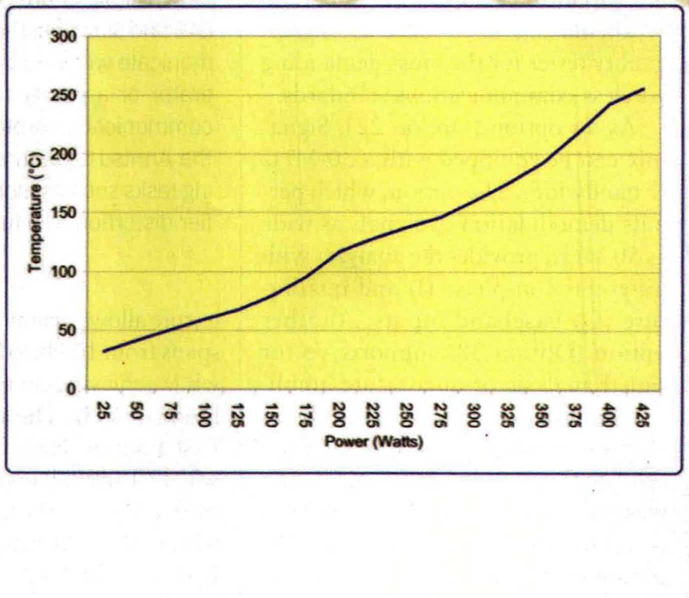

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(1) Based upon internal test. Results may vary.
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MHz to yield the 10.7-MHz IF signals familiar to most receiver designers.

The four-stage, fundamental mixing approach provides resolution bandwidths from 0.1 Hz to 10 MHz while also preserving a wide dynamic range. The displayed dynamic range of the MS2781A is typically better than 150 dB, thanks to a system noise figure of better than 28 dB at 1 GHz and displayed average noise level (DANL) of better than –156 dBm from 10 MHz to 2.5 GHz (in a 0.1-Hz resolution bandwidth) and better than –152 dBm from 2.5 to 8 GHz (in a 0.1-Hz resolution bandwidth). The analyzer boasts a third-order intercept point of better than +23 dBm below 1 GHz and better than +25 dBm at 1 GHz and above. The analyzer has a 1-dB compression point of +10 dBm and accepts input signals to +30 dBm with the aid of its front-end attenuator. The single-sideband (SSB) phase noise achieved by the four-LO receiver chain is better than –118 dBc/Hz offset 100 kHz from a 1-GHz carrier and better than –145 dBc/Hz offset 5 MHz from the same carrier. The analyzer features error-vector-magnitude (EVM) performance of better than 2 percent and wideband CDMA (WCDMA) adjacent-channel-power-ratio (ACPR) measurement capability of better than 82 dB, making it well suited as a signal-quality tester for the most-demanding wireless-communications standards.

As an option (Option 22), Signature can be equipped with a 30-MHz IF bandwidth. The option, which permits demodulation of signals as wide as 50 MHz, provides the analyzer with differential in-phase (I) and quadrature (Q) baseband inputs. Another option (Option 38) supports vector signal analysis of quadrature-amplitude-modulation (QAM) and phase-shift-keying (PSK) signals, allowing an operator to select bit rate, symbol rate, modulation type, and filter methods to modulate captured signals. The option enables a group of automatic, "one-button" measurements, including EVM, carrier leakage, and I/Q imbalance measurements.

Signature's advanced hardware architecture allows operators to set frequency spans from 10 Hz to 8 GHz (full range) while achieving center-frequency resolution of 1 Hz. The analyzer also has a Fast Fourier Transform (FFT) mode with FFT (digital) resolution bandwidths of 0.1 Hz to 100 kHz. Video bandwidths can be selected from 1 Hz to 10 MHz, all with 10-percent accuracy. Signature has overall amplitude accuracy of ±0.5 dB over its full measurement range (amplitude and frequency), with the capability of setting amplitude reference levels from –150 to +30 dBm. Without use of preselection or image-reject filtering, the front-end architecture results in spurious levels that are better than –73 dBc at all offsets and image rejection that is typically better than –100 dB.

Signature provides both frequency-domain and time-domain sweep capabilities. Frequency-domain sweeps can be set from 16 ms to 10,000 s for sweeps as narrow as 10 Hz or as wide as 8 GHz. Time-domain sweeps can be set from 1 µs to 10,000 s. The analyzer can

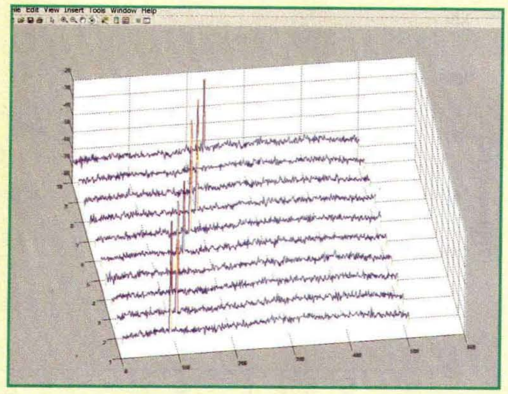
Working Signature With MATLAB And Simulink

JACK BROWNE
Publisher/Editor

Signal analysis with the Signature analyzer takes on new meaning when linked to MATLAB® and Simulink® software tools from The MathWorks (Natick, MA). The combination forms a test/software design environment with seamless flow between measurements and simulation. Using the intuitive language and powerful graphical capabilities in MATLAB, engineers can create and plot complex measurements, such as waterfall displays, power spectral density plots, signal rise/fall time, frequency as a function of time, and even plots of modulation quality. Simulink enhances the capabilities of MATLAB by providing a block-diagram environment to simplify modeling, simulations, and analysis.

For example, this sample string of MATLAB code

```
for i=1:10
   Tracedata(i,:)=Trace1;
   pause(0.1);
end
waterfall (Tracedata);
```



This waterfall plot was generated by MATLAB using 10 traces from the Anritsu Signature analyzer.

works with the Signature analyzer to import 10 signal traces from the instrument, one every 100 ms, and create a waterfall display **(see figure)**. A simple loop or a timer object can make this display update every time the instrument makes a new measurement. Signature automatically creates the variable Trace1 in MATLAB, and updates it whenever a new measurement is made.

While Signature provide an environment for direct analysis of data using MATLAB and Simulink, the MathWorks Instrument Control Toolbox allows users to communicate with and control additional hardware in a test setup, such as a signal generator or a power meter. Support is provided for GPIB, VISA, TCP/IP, and UDP communication protocols. Using MATLAB with the Instrument Control Toolbox and the Anritsu Signature analyzer, users can easily create a test system for performing tasks such as monitoring power changes with temperature or measuring amplifier distortion as a function of signal level.

AWR

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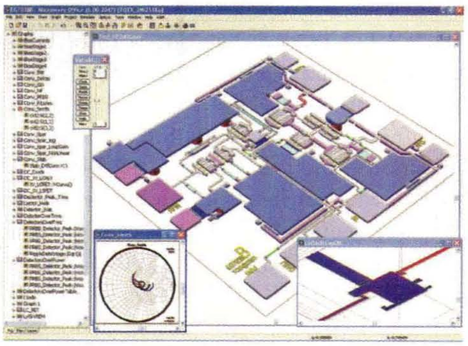

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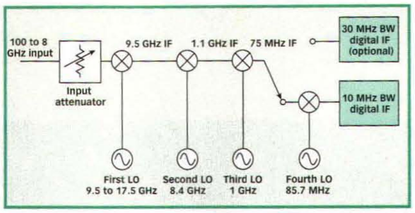
show as many as four graphs on the screen at the same time, using horizontal and vertical limit lines as well as normal and delta marker functions to highlight frequency and amplitude values.

Because Signature is essentially a Windows XP Professional personal computer (PC) as well as an advanced signal analyzer, it can perform measurements and generate documentation quickly and easily. Captured signal information can be saved and imported into Windows XP programs, such as Microsoft Word, Excel, and



2. This block diagram shows the fundamental-frequency, multiple-downconversion architecture used in the Signature analyzer to control spurious and image signals while maintaining an extremely wide dynamic range.

PowerPoint. Visual Basic scripts can also be written into the analyzer. This built-in file portability and Windows XP environment also allows Signature to seamless work with industry-leading analysis tools, such as the MATLAB and Simulink programs (which can run from within the analyzer) from The MathWorks (Natick, MA), for comprehensive analysis of captured signals or signal model generation **(see sidebar).**

Signature's built-in PC/analyzer combination results in an intelligent instrument that can be programmed for single-button control of complex measurement functions (many of which are preset at the factory), including measurements of channel power, burst power, and adjacent-channel power (ACP). The unit provides many ways to transport software and data, with a built-in DVD-ROM/CD-R/W drive, two (front-panel-mounted) USB ports, and GPIB and Ethernet interfaces. A generous (20-Gb) hard-disk drive provides ample storage for captured waveform files, the operating system, and a host of applications. The front panel also includes a connector to power a measurement probe, a headphone jack, while the rear panel includes connectors for access to the first and second IFs, the 10-MHz reference, an input connector for an external frequency reference, a VGA monitor output, a third USB port, a parallel printer port, a power connector for a +24-VDC noise source, and PS2 connections for a computer mouse and keyboard. P&A: $49,500; 16 wks. **Anritsu Co., Microwave Measurements Div., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (800) ANRITSU, (408) 778-2000, FAX: (408) 778-0239, Internet: www.us.anritsu.com.**

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Software Speeds Filter Selection

The new Filter Wizard software from K & L is a tremendous aid for filter specifiers, allowing them to experiment with performance trade-offs and even download S-parameters for modeling.

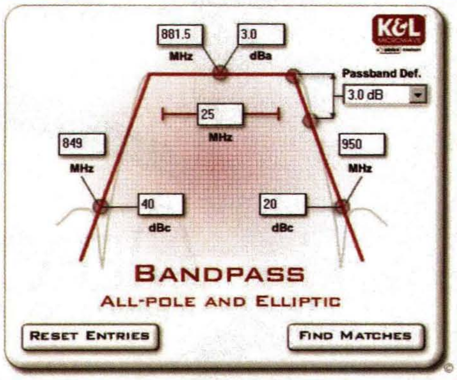
JACK BROWNE
Publisher/Editor

Filter specifiers are accustomed to combing through catalogs, in search of a component that will match their desired set of performance parameters. By combining the power of the Internet with its own extensive filter database and filter-design software, however, K & L Microwave has developed a specifying tool that is sure to send a great many filter catalogs to the trash. Called K & L Filter Wizard™, the online program is free for visitors to the K & L website at www.klmicrowave.com.

K & L's customers, of course, will recognize that Filter Wizard is actually an evolution of earlier filter-specifying tools developed by the company. Beginning with the firm's breakthrough Reflex program in the latter 1980s—one of the first software programs that allowed users to essentially design their own filter model—and continuing with the CD-ROM-based KeL-fil software tool that helped guide users in the selection of ceramic-based filters, the KeL-com version for lumped-element filters and, most recently, the Mini-Max selection program for users of surface-mount filters, the company has established a history of providing value-added tools to its customers free of charge. Such tools have not only simplified the specification process, but also doubled as educational resources to help train young engineers in various aspects of filter design and performance.

With Filter Wizard, the company has ambitiously hit a new high-water mark for filter-specifying tools. The on-line program, which is expected to launch during the upcoming Microwave Theory & Techniques Symposium (MTT-S) next month (Fort Worth, TX, June 8-10, 2004), is both powerful and easy to use. The first version covers all-pole and elliptical (pole-placed) bandpass filters; later this year, the software will be upgraded to include other filter responses, such as lowpass, highpass, and band-reject filters.

The opening screen of K & L's Filter Wizard **(Fig. 1)** indicates the four basic steps to using the tool: enter specifications, review results of the search based on those specifications, drill down to fur-



1. The opening screen of the Internet-based Filter Wizard program allows operators to enter key performance parameters for a filter of interest, including center frequency, bandwidth, and stopband frequencies.

ther details on a filter or filters of interest, and send an e-mail request for quote to K & L. A large response curve for a typical bandpass filter highlights this opening screen, with blank boxes left for operators to enter their desired specifications, such as center frequency and bandwidth (both in MHz), the passband definition (such as 0.5 dB, 1 dB, 3 dB, or equiripple), passband ripple, and

Filter Type:	Product ID:	IL:	Size:	Relative Price:	K&L
KeL-fil	5DR35-881.5/T25-1.8	2.84 dBa	1.28 x 0.75 x 0.27 inches	$$$$$	Details...
KeL-fil	5DR33-881.5/T25-1.8	2.84 dBa	1.53 x 0.74 x 0.26 inches	$$$$$	Details...
KeL-fil	5DR31-881.5/T25-1.8	2.84 dBa	1.38 x 0.86 x 0.26 inches	$$$$$	Details...
Cavity	5C40-881.5/T25-O/O	0.65 dBa	5.88 x 1.24 x 3.85 inches	$$$$$	Details...
Cavity	5C42-881.5/T25-O/O	0.42 dBa	9.38 x 1.94 x 3.85 inches	$$$$$	Details...
Cavity	5CS10-881.5/T25-O/O	1.09 dBa	2.08 x 1.33 x 1.92 inches	$$$$$	Details...
Cavity Elliptic	4CS10-881.5/T25-O/O (EL10/-4.36)	0.88 dBa	1.42 x 1.33 x 1.92 inches	$$$$$	Details...
7 Filters Found	Show All	Units:	Inches		

2. The results of a search include comparisons of different technology solutions, size, and relative cost, with the option of clicking on the "Details" button for more information.

rejection at specific frequencies on the lower and upper filter skirts. Once entered, the user can begin the search of K & L's extensive filter database for any and all filters meeting these specifications (as minimum requirements) by simply clicking on the "Find Matches" button. The resulting search spans products covering one of the broadest ranges of unloaded Q in the industry. A "Reset Entries" button is provided to allow the user to return to a set of default inputs.

The search results are presented in tabular form **(Fig. 2)**, with the filter type, product identification number, insertion loss, and size listed for comparison. One particularly useful entry in this table is the listing for relative price, allowing users to not only compare the relative expense of each of the selected filters, but the costs of the various filter *technologies*, such as the KeL-fil, cavity, and cavity elliptic filters selected in Fig. 2. On this screen, operators have the option of displaying physical dimensions in SAE (inches) or metric (millimeters) units.

From this tabular view operators can click on the "Details" button for any one of the listed filters and shift to a screen with more complete product details **(Fig. 3)**, including a spectral plot showing insertion loss, return loss, and group delay. Users can zoom in and out on this spectral display, for example, to take a closer look at passband ripple. The information listed in the "Details" screen includes a comparison of all requested specifications with the actual specifications for that filter. The example of Fig.

(continued on page 138)

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Gali 1	DC-8000	12.7	12.2	4.5	27	108	40	3.4	.99
Gali 21	DC-8000	14.3	12.6	4.0	27	128	40	3.5	.99
Gali 2	DC-8000	16.2	12.9	4.6	27	101	40	3.5	.99
Gali 33	DC-4000	19.3	13.4	3.9	28	110	40	4.3	.99
Gali S66	DC-3000	22	2.8	2.7	18	136	16	3.5	.99
Gali 3	DC-3000	22.4	12.5	3.5	25	127	35	3.3	.99
Gali 6F	DC-4000	12.1	15.8	4.5	35.5	93	50	4.8	1.29
Gali 4F	DC-4000	14.3	15.3	4.0	32	93	50	4.4	1.29
Gali 51F	DC-4000	18.0	15.9	3.5	32	78	50	4.4	1.29
Gali 5F	DC-4000	20.4	15.7	3.5	31.5	103	50	4.3	1.29
Gali 55	DC-4000	21.9	15.0	3.3	28.5	100	50	4.3	1.29
Gali 52	DC-2000	22.9	15.5	2.7	32	85	50	4.4	1.29
Gali 6	DC-4000	12.2	18.2	4.5	35.5	93	70	5.0	1.49
Gali 4	DC-4000	14.4	17.5	4.0	34	93	65	4.6	1.49
Gali 51	DC-4000	18.1	18.0	3.5	35	78	65	4.5	1.49
Gali 5	DC-4000	20.6	18.0	3.5	35	103	65	4.4	1.49
Gali 74	DC-1000	25.1	19.2	2.5	38	120	80	4.8	2.35

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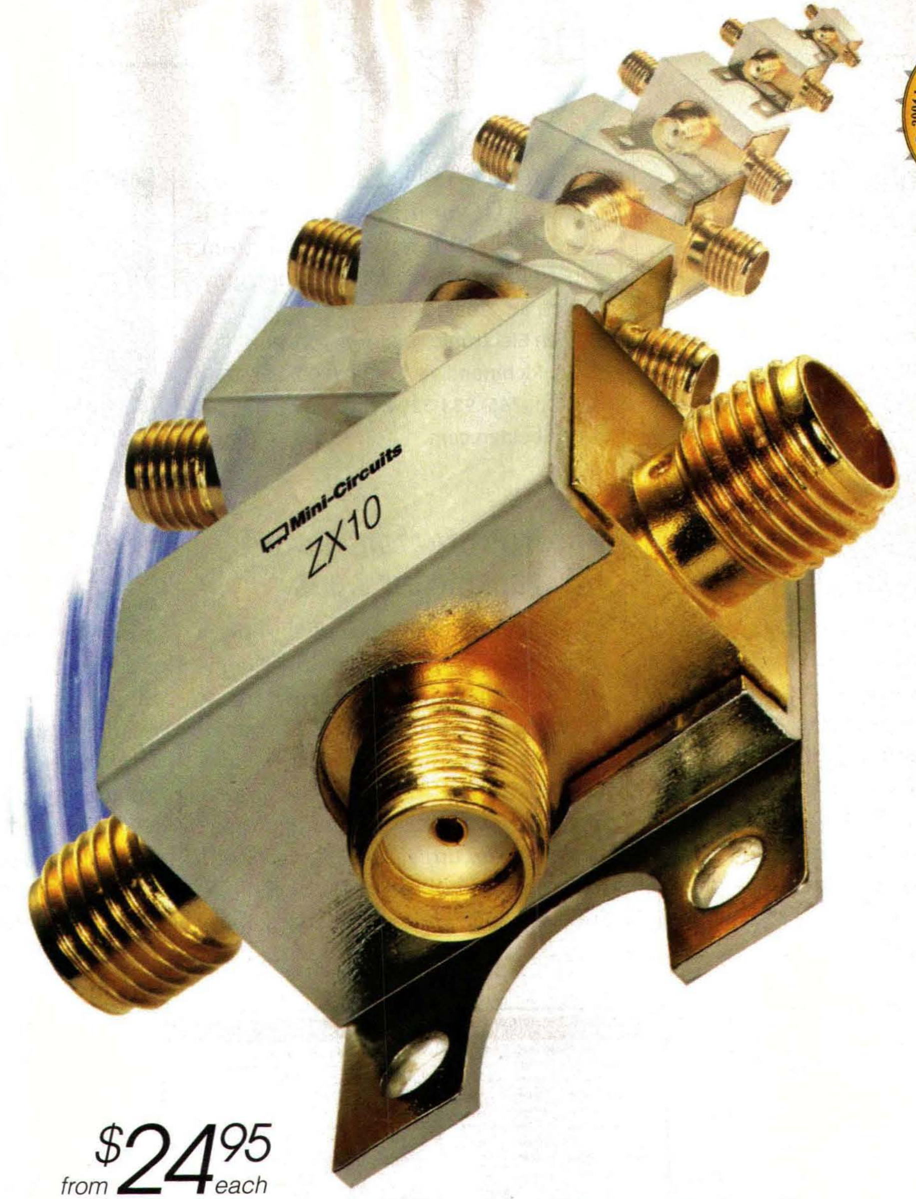

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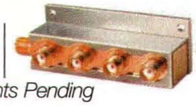
ZX SERIES A new breed of SMA power splitters is small in size, small in price, and big on features. They're the ZX10 series of 2way and 4way power splitters from Mini-Circuits! These 50 ohm splitters give you excellent performance with low insertion loss and high isolation. Each easily mountable model is extremely small in size, so you conserve real estate in laboratory, production, and system environments. And thanks to exclusive patent pending unibody construction, ZX10 splitters are rugged and phenomenally low in price. All models are **IN STOCK!** So contact Mini-Circuits now for individual units, or buy the whole collection for the lab, and never get caught short. Have the signal splitting and combining power you need, on hand when you need it, with ZX10!

Mini-Circuits...we're redefining what VALUE is all about!

TYPICAL SPECIFICATIONS

2WAY-0° Model	Frequency (GHz)	Isolation (dB)	Insertion Loss (dB) Above 3.0dB	Price $ea. (Qty.1-24)
ZX10-2-12	.002-1.2	21	0.5	24.95
ZX10-2-20	.2-2	20	0.8	24.95
ZX10-2-25	1-2.5	20	1.2	26.95
ZX10-2-42	1.9-4.2	23	0.2	34.95
ZX10-2-71	2.95-7.1	23	0.25	34.95
ZX10-2-98	4.75-9.8	23	0.3	39.95
ZX10-2-126	7.4-12.6	23	0.3	39.95
4WAY-0°			Above 6.0dB	
ZX10-4-11	.8-1.125	20	0.6	38.95
ZX10-4-14	1.1-1.45	20	0.8	38.95
ZX10-4-19	1.425-1.9	20	0.75	38.95
ZX10-4-24	1.675-2.35	20	0.9	38.95
ZX10-4-27	2.225-2.7	20	1.0	38.95

2Way-0°
(L).74"x(W).90"x(H).54"
Dimensions include case bracket



Patents Pending

NEW!
4Way-0°
(L)2.04"x(W).60"x(H).75"
Dimensions include case bracket

***K1-ZX10 Designer's Kit** (2Way)*
1 of Each Model (7 total) $199.95
FREE Deluxe Wood Storage Case!

Detailed Performance Data & Specs Online at: ***www.minicircuits.com/ZXSPLITTERS.pdf***

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P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 For quick access to product information see MINI-CIRCUITS CATALOG & WEB SITE

The Design Engineers Search Engine** Provides ACTUAL Data Instantly From MINI-CIRCUITS At:* ***www.minicircuits.com

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See our 244 page RF/IF Designer's Guide in EEM (Electronic Engineers Master)

Lightweight Cables Are Designed For Mobile Use

AN RG-179 TYPE COAXIAL CABLE, the Brilliance DigiTruck™ 179DT lightweight, Precision Video coaxial cable, is designed specifically for use in mobile television

broadcast trucks where equipment load-weight is a prime concern and space in the truck is scarce. This compact cable delivers reliable performance in analog, SDI, HDTV, and AES/EBU digital audio transmissions. In comparison to standard Mini RG-59/U type coaxes, the 179DT weighs 60 percent less and requires up to 40 percent less space. Standard Mini RG-59/U type coaxes have a nominal OD of 0.159 in.; the 179DT has a nominal OD of 0.1 in. The 179DT is available in 10 jacket colors: red, green, blue, white, yellow, brown, orange, gray, violet, and black.

Belden Electronics Division, P.O. Box 1980, Richmond, IN 47875; (800) BELDEN-4, FAX: (765) 983-5294, Internet: www.belden.com.

Filter Protectors Target RF Transmitter Apps

THE HF SERIES of combiner/high-power filter protectors protects multiple (combined) or high-power single RF transmitter applications where DC voltage is not required. Covering a frequency range from 100 up to 700 MHz, the protectors offer low throughput energy. Capable of handling up to 750 W, the advanced filter design of the HF Series features multi-strike capability fully weatherized hous-

ing and is DC blocked. Insertion loss is very low at 0.18 dB or less. Comprehensive testing has demonstrated low surge throughout measuring significantly less than 5 microJoules at 3 kiloAmperes (8/20 microsecond waveform). The HF Series is designed for an operating temperature range between –50 up to +85°C and is available with standard N and 7/16 DIN connectors. Bulkhead or flange mounting is also catered for.

PolyPhaser, A Smiths Interconnect Co., 225 Park Pl., Minden, NV 89423; (775) 782-2511, FAX: (775) 782-4476, Internet: www.polyphaser.com.

PRODUCT *technology*

SOFTWARE

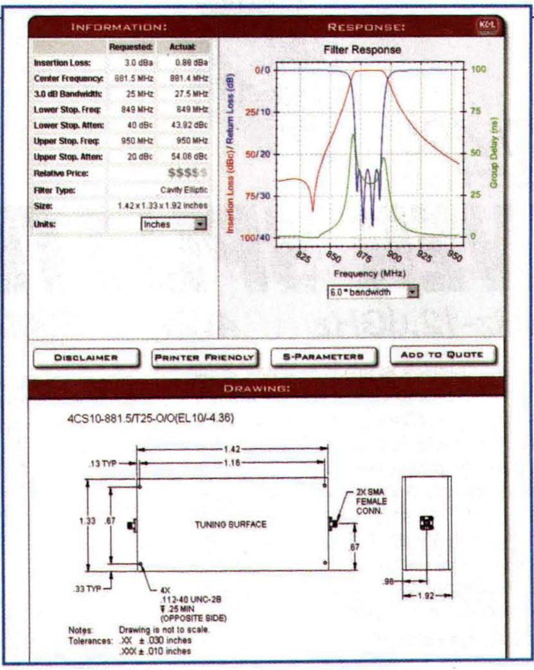
(continued from page 134)

3 shows how the program matches the key specifications, meeting both the stopband attenuation requirements and the desired insertion loss. The "Details" screen repeats the dimensional information of the previous screen, but also includes a package outline drawing, complete with coaxial connectors in the case of this example, and a button for downloading S-parameters.

The final step in using K & L's Filter Wizard is the "Request for Quote" screen, which smartly includes not only the requested filter's identification number, but also key specifications, such as the center frequency, bandwidth, and stopband frequencies. This screen prompts a user for name, address, e-mail, and other contact information, and provides room for additional comments and requirements (using multiple screens), including screening and environmental requirements. By clicking on the "Process Request" button at the bottom of the screen, an e-mail with the quote information is sent to K & L where it will be processed within 24 hours. If further information is needed to process the quote, K & L staff will contact the customer.

In addition to *selecting* filters, Filter Wizard allows operators to *design* cavity filters for optimal physical dimensions given a set of specifications. Specifiers can actually develop a cavity filter solution for minimal size while still meeting their electrical performance requirements.

The initial version of Filter Wizard covers all-pole and pseudo-elliptic bandpass filters and provides solutions by means of four technologies: ceramic, lumped component, cavity, and waveguide. Highpass and lowpass filters will be added to the follow-up version (expected by the end of summer), followed by band-reject filters and diplexers in subsequent versions. **K & L Microwave, Inc., 2250 Northwood Dr., Salisbury, MD 21801; (410) 749-2424, FAX: (410) 749-5725, e-mail: sales@klmicrowave.com, Internet: www.klmicrowave.com.**



3. The "Details" screen provides not only the basic specifications, but performance plots and package outline drawings.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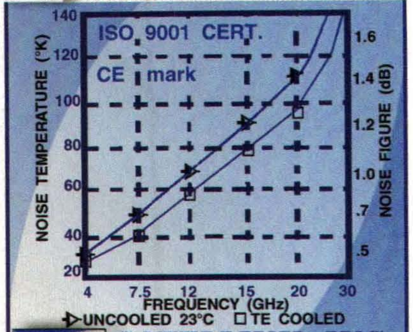
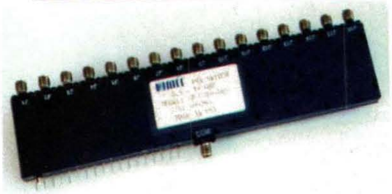

ISO 9001 CERT.
CE mark
NOISE TEMPERATURE (°K)
NOISE FIGURE (dB)
FREQUENCY (GHz)
UNCOOLED 23°C
TE COOLED



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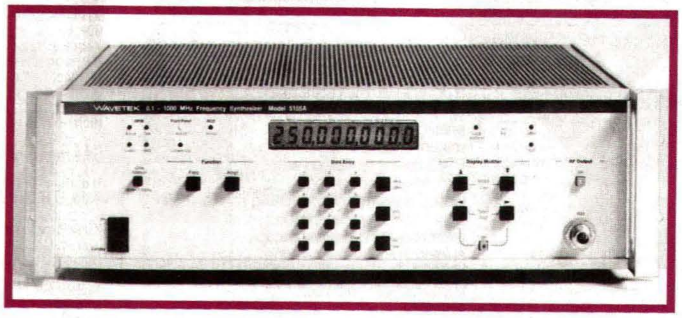
looking back



NINETEEN YEARS AGO, an advertisement from Wavetek San Diego (San Diego, CA) directed visitors to that year's MTT-S (in St. Louis, MO) to try the model 5155A frequency synthesizer, with 1-GHz bandwidth and 1-µs switching speed, claimed to be the world's fastest synthesizer.

next month

Microwaves & RF June Editorial Preview

Issue Theme: Defense Electronics

News

June offers a closer look at one of the fastest-growing, albeit difficult-to-quantify, markets for high-frequency electronics: homeland security. The market, which consists of communications and surveillance devices for local, state, and federal agencies, also includes such devices as ultra-wideband (UWB) ground-penetrating radars and RFID tags and transponders. Who is supporting this growing market and how? Don't miss the answers in this Special Report. Also, in June, an exclusive celebration of one of the high-frequency industry's longest-running success stories: Don't miss coverage of Narda Microwave's 50th birthday party in the June issue. Read how this tiny Long Island firm grew into one of the leading suppliers of military, commercial, and safety equipment worldwide.

Design Features

June features a strong lineup of technical articles with commercial and military implications. For example, a regular contributor from Analog Devices details how the next generation of logarithmic amplifiers (logamps) can be used in wide-dynamic-range commercial and military receivers, while an author from UCLA explores the generation of ultrawideband (UWB) arbitrary waveforms by means of optical spectrum sculpting. Additional design features review some of the requirements of microwave repeaters, explain how to make accurate in-phase and quadrature (I and Q) component imbalance measurements, and how to design a tracking generator for a microwave spectrum analyzer.

Product Technology

June's Product Technology unveils a new line of microwave frequency synthesizers that combine the best aspects of several technologies, including phase-locked loops (PLLs), fractional-N circuitry, and direct-digital synthesis (DDS), to achieve high resolution with low phase noise and spurious content. Additional Product Features explore a flexible PXI-based vector signal generator capable of producing a wide range of modulated carriers to 2.7 GHz, a transceiver integrated circuit (IC) that works for all three 802.11a/b/g WLAN systems, and a conformance test solution covering all the features and timing requirements of IEEE 802.11 WLAN standards.